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EDITORIAL NOTES.

THE Swiney Lectures for 1920 in connexion with the British Museum (Natural History) will be delivered by J. D. Falconer, M.A., D.Sc., F.R.S.E., etc., on Mondays, Wednesdays, and Fridays from November 8 to December 3 at 5.30 p.m. in the Geology Lecture Theatre, Royal School of Mines, Prince Consort Road, South Kensington. The subject of the lectures, which will be illustrated by lantern slides, is "The Modelling of the Earth's Crust". Admission is free.

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On November 7 Professor Alfred Gabriel Nathorst, of Stockholm, will celebrate his 70th birthday. In many fields Nathorst has left a deep imprint on our science. As a specialist he ranks among the most eminent of palæobotanists, for his scientific results, for his invention of new methods, and for the large and admirably arranged collection that he has established in the Swedish State Museum. As a pupil and follower of Linnarsson his early studies were largely on the Palæozoic rocks of Southern Sweden, where the curious markings in the Eophyton sandstones led to his classical memoir on the origin of such tracks. His familiarity with the rocks in the field, with their fossils in the laboratory, and with the writings of his predecessors in the library rendered him the most appropriate author of that useful work *Sveriges Geologi*. His love of sport (to which the deafness of his later years is due) fitted him to lead those exploring expeditions to Spitsbergen and Greenland which have maintained the high place already gained by Sweden in geographical research. British geologists, who are proud to greet Professor Nathorst as almost the senior Foreign Member of the Geological Society of London, will send him their congratulations on achieving three-score years and ten of vigorous and fruitful life.

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Mr. R. Bullen Newton, F.G.S., lately retired (under age-limit) from the Geological Department in the British Museum (Natural History), has gone upon an expedition to Trinidad to examine the fossiliferous deposits yielding petroleum in that island. These

beds were noticed in the GEOLOGICAL MAGAZINE by the late R. J. Lechmere Guppy (see GEOL. MAG. 1865, p. 256; 1866, p. 179; 1870, p. 235; 1874, pp. 404–33; 1892, p. 331; 1900, p. 322), and of late years have attracted much attention.

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STANLEY SMITH, M.A., D.Sc., has been appointed Reader in Geology in the University of London (Bedford College) in place of Miss C. A. Raisin, D.Sc., who has resigned.

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THE "David Syme" prize of £100, with medal, for scientific research for the year 1920, has been awarded to Mr. Frederick Chapman, A.L.S., palæontologist to the National Museum and lecturer in palæontology in the University of Melbourne.

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DR. GRIFFITH TAYLOR has been appointed to the newly established professorship of geography in the University of Sydney. After graduating at Sydney Dr. Taylor became a research student of Emmanuel College, Cambridge, and was afterwards chief geologist in Captain Scott's Antarctic expedition. Since then he has been connected with the Federal Meteorology Bureau in Melbourne.

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A FREQUENT contributor to the GEOLOGICAL MAGAZINE, Dr. Arthur Holmes, Assoc.R.C.Sci., F.G.S., Imp. Coll. Sci. Tech., sailed for Burma in September last for several months (on leave) to carry on geological investigations in that region as to oil and other economics.

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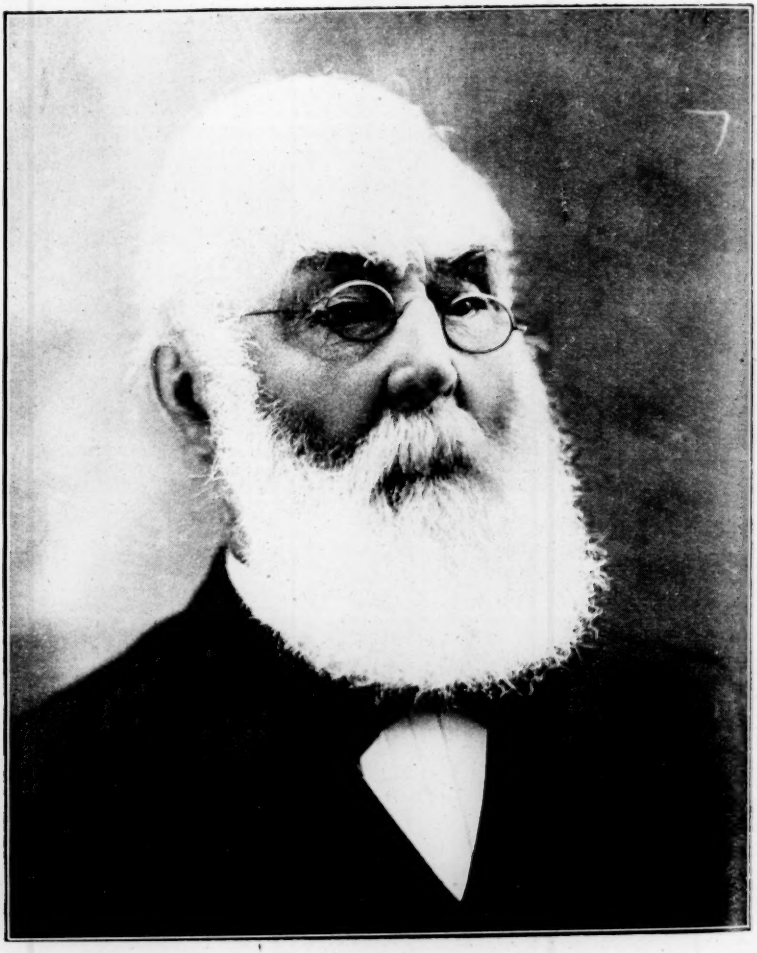
AT the present day good exposures of the Cambridge Greensand are seldom seen, but an excellent opportunity of studying this interesting deposit is now to be found at the Norman Cement Works, near Cambridge. The company works the lower part of the Chalk Marl for cement, and excavations are usually carried down to a few feet above the Gault. Some new plant is now being installed in the pit, requiring considerable excavation for foundations. The base of the Chalk Marl and the Cambridge Greensand have been dug through and about 5 feet of Gault is exposed. There is, therefore, an excellent clean-cut section showing the Cambridge Greensand, and its relation to the beds above and below. The pockety surface of the Gault, bored by animals living in the Greensand sea, is well seen, since the burrows are filled with a light greyish-green sand, contrasting well with the darker Gault. The phosphatic nodules characteristic of the bed are well developed, and the gradual passage upward into the Cenomanian is clear. No doubt the Manager of the Company would be pleased to allow any geologist interested in this bed to visit the pit while this excellent temporary section is exposed.



James Hall

A great American Geologist of the last Century.[1]

PROFESSOR JAMES HALL (1811–98).

(PLATE X.)

JAMES HALL'S active career in American geology extended over sixty-two years of uninterrupted official connexion with the State of New York, a record which stands unsurpassed in the history of official science. At the age of 25 Hall entered the geological service of New York upon the organization of the Natural History Survey in 1836, and his service was terminated by death in 1898, at the age of 87 years. So great was the span of his life that it not only covered but formed in itself a large share of the evolution of geological science in America. James Hall's enthusiasm for his work never diminished. His death was but the incident of a day, and his life, even to that day, was inspired by the undivided purpose to develop and advance his science. Such a life could not fail to be immensely productive, and his was rich in its output from the publication of his first great quarto report on the Geology of the Fourth District of New York (1843) to the last of the thirteen quarto volumes of the Palæontology of New York.

When the Natural History Survey was organized Hall entered upon it for the first field season in 1837, as an assistant to Dr. Ebenezer Emmons, in the crystalline rock region of the Adirondack Mountains. The second year found him in charge of the "Fourth District" of western New York, then a sparsely settled and still heavily timbered region. Here he gradually unfolded the beautifully ordered succession of the Palæozoic rocks with their wealth of fossil life, and it was their richness in fossils that gave birth to his desire and purpose to describe and figure them, and with them to verify and establish the classification of the "New York Formations" as set forth by the conclusions of his colleagues on the State Survey.

No provision had been made for such a study of the fossils in the original plans of the Survey; when, therefore, the time arrived that the work was officially concluded in 1843, Hall succeeded in obtaining the sanction of the State, and was himself commissioned to prosecute this work and prepare a report on the Palæontology of New York, which was to be in one volume and to be completed in one year. The volume actually occupied three years, and was followed by twelve more volumes, under the title of *The Palæontology of New York* (which appeared successively in a period of more than half a century). The work is still going on vigorously. The "New

[1] A brief obituary of Professor James Hall, For. Memb. Geol. Soc. Lond. 1848, appeared in the GEOL. MAG. for September, 1898, pp. 341–2. By the kindness of his successor, Professor John M. Clarke, LL.D., For. Corr. Geol Soc. Lond., we are enabled this month to publish some additional notes of our old friend and fellow-worker, together with an excellent portrait.

York Series of Geological Formations", as set forth by the four State Geologists, elicited Hall's ardent support in all his descriptive work upon the fossils of these formations. Some of its terms antedated those now in common acceptance; thus, "Champlain" was an earlier and better defined name than Ordovician or Lower Silurian; Erian an earlier and more clearly defined term than Devonian; and on the basis of priority of fossil evidence the term "Taconic", of Emmons (though this was fought over for two generations and not highly regarded by the New York geologists), has on the basis of its fossils a chronologic right of way over the name Cambrian. It was only very slowly and with obvious reluctance that Hall yielded to the personal arguments of Murchison in adopting the term Silurian for the terms in the series that are now commonly or provisionally grouped under the name Ordovician, and it is very interesting to a student of the development of geological ideas in America to see how these now commonly accepted divisions of the lower rocks had to struggle for recognition in this part of the Western Hemisphere.

The adoption, on *palæontological* grounds, by the late James Hall and other American geologists of the common English (and European) names for the divisions of the Palæozoic rocks, has been already attended with the most splendid results, and if carried out (internationally) by the authors of our textbooks and the professors in our colleges will enable us to synchronize all the great geological formations of the globe.

Hall was born and spent his boyhood along the coast of Eastern Massachusetts, and acquainted himself with the marine life of those shores as well as a boy could do who had no books or teachers. He walked from his home at Hingham, Mass., a distance of 200 miles, to attend the Rensselaer School at Troy, not far from Albany, N.Y., and his knowledge of the common life of the sea and his wide acquaintance with botany were always put to their ultimate service in his reconstruction of the extinct life of the Palæozoic rocks. His work was of necessity largely descriptive, as he was engaged in the portrayal of the succession of fossil faunas as a pioneer in a virtually unknown field. All students of his books will bear testimony to the accuracy and fidelity of his work, and the volumes of his early years are still as essential to the study of the Palæozoic faunas of America as the works of Murchison to a knowledge of the "Silurian System". Through his impressive personality, his unrestrained vigour, and his ability to convince persons in authority that he was in dead earnest, Hall was enabled to keep his palæontological work generously supported by the State of New York, even when other departments of science were languishing for public support. But he did all this much as St. Paul carried on his missionary endeavours; he was often in trouble, and not infrequently had to fight the wild beasts at court who thought his preaching foolishness.

Incidentally to his other work, Hall did many fine pieces of closely

analytical morphology, which were in large measure the product of his own studies. He had also a keen appreciation of the necessity of making his work intelligible to students by the excellence and accuracy of his illustrations; to secure this he drew his draughtsmen and illustrators, his lithographers and pressmen, from various quarters of the world, and carried out the printing under his own eye and within easy reach of his own laboratory. A word is appropriate in regard to Hall's laboratory. In the early fifties he established himself and his collections in a building that he had specially arranged for the prosecution of his work, and then began to gather about him men who were to assist him in the working out of the ever-accumulating materials for his great undertaking. In this laboratory there entered, and in due time emerged, a long line of assistants who afterwards acquired an established place in American geological science. Among these were Fielding B. Meek, Robert P. Whitfield, Ferdinand V. Hayden, Charles A. White, Charles D. Walcott, Charles E. Beecher, John M. Clarke, Charles Schuchert, and a number of others. The old laboratory still stands and has happily been set aside by the city of Albany as a place not to be effaced, and it bears upon it a commemorative tablet attached thereto by the Association of American Geologists.

Mr. Hall was naturally not content with activities confined to the State of New York. He had a colossal capacity for work, and was at one and the same time during the later fifties State Geologist of Iowa, State Geologist of Wisconsin, in active association with Sir William Logan on the Canadian Survey, and also prosecuting the work in New York. It was in these busy years that, as President of the American Association for the Advancement of Science, he prepared and delivered his most philosophical discussion on a geological theme, "The Origin of the North American Continent." In this he set forth an entirely new explanation of mountain building, which is still highly regarded, especially by the French geologists, under the designation of the Law of James Hall. While very seriously engaged in these undertakings, almost every State in the Union, as it proceeded towards the organization of a geological survey, made proposals for his services. Hall, however, really cared for this outside work only in so far as he could touch its fossils, and it is because he ignored reports and turned all his efforts to an exposition of the fossils that the support of Iowa and Wisconsin was finally withdrawn. Naturally, in his later years, though with many imperative interests, he became more and more dependent upon his assistants for the preparation of his great volumes.

There are few left who still remember the singular combination of traits that this remarkable man presented. He was gentle, affectionate, and confiding; on the other hand, he was suspicious, irascible, and imperious, and such a contradictory combination of qualities required patience and careful adjustment on the part of his associates. For fifteen or twenty years Hall was much engaged

with the organization of the International Congress of Geologists, which originated from a convocation of geologists held in Buffalo, N.Y., in 1876. Hall was chairman of the organizing committee and was chairman of the first congress that met in Paris under the presidency of Professor Hebert. He followed the congresses eagerly at their subsequent sessions, and at the age of 86 he went with his daughter to Europe, passing through England and visiting the British Museum (Natural History) on his way to St. Petersburg to attend the session of that year, and going even so far afield as the Caucasus Mountains. This last great experience in his life was something of a triumphal progress, for he was venerable not only in years but in experience, and carried with him a most impressive personality. His strong vigorous body, his head adorned by snow-white hair and flowing beard, and his cheeks, even at that age, bearing the ruddy tints of vigorous health, did not fail to attract attention wherever he went, and his tour through Russia and the states of Europe commanded wide attention.

James Hall has left an indelible stamp upon the history of American geology. The time will never come when his work can be laid aside as no longer of service or needed in aid of the progress of geological knowledge. What he did was fundamental, and the superstructure which his successors have laboured to raise can rest securely upon his foundations. Hall was naturally much honoured by scientific societies and by the bestowal of many orders and decorations. He became a Foreign Member of the Geological Society of London in 1848.

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Encouraged by such early pioneers as James Hall and his contemporaries, a host of modern palæontologists have boldly sailed into those little-known seas of past geologic time, and have discovered new lands and new faunas and floras, adding vastly to our knowledge of the buried past, furnishing at the same time reliable landmarks for the stratigraphical worker, and thus transforming geology from a dead into a living science.

ORIGINAL ARTICLES.

The Quartzose Conglomerate at Caldon Low, Staffordshire.

By J. Wilfrid Jackson, F.G.S., and J. Kaye Charlesworth, M.Sc., Ph.D.

In the Geological Magazine for February, 1919 (pp. 59–64), one of the present writers, in collaboration with W. E. Alkins, described an exposure of a quartzose conglomerate on the north-west flank of Caldon Low. The conclusions arrived at in that paper were adversely criticized by F. Barke, Wheelton Hind, and A. Scott in a later paper in the same Magazine.[1] These writers maintain that the conglomerate was not a contemporaneous deposit, but an assemblage of materials, analogous to that seen in the Weaver Sand-pits, south of the Ribden Mine, about one and a quarter miles away, which had filled up a solution cavity in the limestone and had become consolidated by the percolation of calcareous matter.

The present paper is written with the object of refuting the statements made by these writers as to the mode of origin and the age of the conglomerate. During the last twelve months quarrying operations have revealed tectonic features which clearly prove that the quartzose conglomerate is a true "intra-formational conglomerate", as suggested in the original paper.[2]

To clear the ground it will be convenient to give a short description of the Weaver Sand-pits.

The Weaver Sand-pits.—The deposits in these pits consist chiefly of incoherent sands, clays, and pebbles, and closely resemble those of the series of pockets in the limestone of the high ground of Derbyshire from Parsley Hay to Wirksworth. The principal pit in the Weaver series, and the one now working, differs from the adjacent ones and from the Derbyshire pits in containing blocks of hard sandstone, with and without pebbles, which are obviously residual Bunter beds. These blocks are erroneously regarded by Messrs. Barke, Hind, and Scott as due to the consolidation of part of the contents of this pit.[3] They further state that they are similar lithologically to the infilling at Caldon Low. The remains of a similar sand-pit are still to be seen close to the road to Cauldon village, 1 mile N.N.W. of the Weaver pits, and a quarter of a mile S.W. of the quartzose conglomerate under discussion. In this pit a block of black Pendleside shale, containing *Posidoniella minor*, was found by J. Allen Howe, and duly recorded in his paper, "Notes on the Pockets of Sand and Clay in the Limestone of Derbyshire and Staffordshire."[4]

[1] Geol. Mag., Vol. LVII, 1920, p. 76.
[2] Ibid., Vol. LVI, 1919, pp. 59–64.
[3] Ibid., Vol. LVII, 1920, p. 81.
[4] Trans. North Staffs Field Club, vol. xxxi, 1897, p. 144.

Mr. Howe also noted the occurrence of large blocks of sandstone lying in the pit, which he was inclined at the time to regard as the remains of an outlying extension of the Bunter or Keuper beds.[1] Many of these blocks, some containing pebbles, are still to be seen here. Traces of other deposits of sand and pebbles are still visible in this neighbourhood, especially to the S. and S.E. of Milk Hill, near Waterhouses.

The presence of black shale in these pits is not peculiar to the Staffordshire series, as we have noted its occurrence in the Longcliff Pit, and in one near Parsley Hay, Derbyshire. In both cases the shale was well-bedded and in a vertical position, as if it had dropped in bodily. In the latter locality the shale contained *Posidoniella* and obscure plant remains.

That the whole series of these pits, both in Derbyshire and in Staffordshire, is pre-Glacial in age is clearly proved by the presence of Glacial Drift overlying them. During our survey of the pits recently we made a careful examination of the overburden in every case, and found that it was sharply marked off from the underlying sands and gravels, especially in the Derbyshire series. At one of the pits at Parsley Hay we obtained a large boulder of Eskdale granite and two of Borrowdale ash from the overburden, thus proving it to be Drift of the Irish Sea ice-sheet. At the Washmere Pit, near Newhaven, the same Drift contained ice-scratched boulders of dolerite, Carboniferous Limestone, and sandstone. The Drift overlying the disused pit at Minning Low yielded chert, Magnesian Limestone, dolerites, grits, etc. A dolerite boulder was also found in the Drift at the Longcliff Pit, while from the Drift at the working pit at Ribden we obtained a large ice-scratched boulder of gritstone. The presence of Boulder-clay here has long been known, and was described by G. Maw in 1867.[2]

The Quartzose Conglomerate.—In the earlier paper [3] it was pointed out that the condition of the section exposed in September, 1918, rendered the relation of the conglomerate to the massive Caldon Low limestones (*Humerosus* beds) somewhat doubtful, but the available evidence suggested an unconformity or a fault. Recent quarrying has revealed a slickensided surface running W.S.W.–E.N.E. along the truncated ends of the horizontal *Humerosus* beds, thus suggesting movement of the quartzose conglomerate and associated beds in a more or less horizontal direction.[4] Blocks of the conglomerate also show the same slickensided surface. It is clear from this fact that the conglomerate does not occupy its original position.

[1] Ibid., p. 149.
[2] Geol. Mag., Vol. IV, 1867, p. 250, Fig. 7.
[3] Ibid., Vol. LVI, 1919, p. 60.
[4] This fault is probably the continuation of the mineral vein marked on the 1 in. Geological Map, No. 72, N.E. The vein is now destroyed by quarrying operations.

In their paper on the subject,[1] Messrs. Barke, Hind, and Scott give a diagrammatic section (E.–W.) of the quartzose conglomerate and adjacent limestones at Caldon Low. This shows to the west a basin-like mass of conglomerate occupying a hollow in the limestone, while towards the east two vertical pipes of conglomerate are shown leading down to two bands of the same material, one of which connects with the main mass of conglomerate in the cavity. This band is shown transgressing other beds in the section. It is suggested by these writers "that the conglomerate fills a subterranean hole in the limestone, probably formed by solution, the thin bands representing several underground watercourses leading into the main hollow" (op. cit., p. 78). We have been unable to find any evidence to justify this interpretation. On close examination in the field it is seen that the beds shown to the east of the main mass of conglomerate are, in fact, a series of impure limestones exhibiting current structures. They consist of alternating beds of sandy and pebbly limestones, lenticular quartz conglomerate, and beds composed of fragmentary shells of brachiopods and crinoid debris with included sand grains, the whole dipping N.N.W. at an angle of 30 degrees. The amount of sandy and pebbly detritus varies somewhat in beds on the same stratigraphical horizon, this having been doubtless brought about by changes in the currents bringing in the material. It is plainly seen that these limestones are the marginal deposits of the coarser conglomerate, which, in our opinion, fills an old channel. The top of this section, immediately under the surface soil, consists of a fairly thick bed crowded with crinoid-stems resting conformably on the conglomeratic beds.

From the foregoing description it will be seen that the idea of the existence of pipes from the surface is founded on a misinterpretation of the facts. The presence of large quantities of sand-grains and quartz-pebbles disseminated in beds of shelly limestones, etc., throughout this section militates against any such idea as piping.

Lower down the slope of the hill, and a little to the west of the section just described, the quartzose conglomerate is to be seen in the face of a low ridge running approximately E.N.E.–W.S.W., bounding the railway siding. The height of the section here, from the quarry platform to the surface of the ground, is about 28 feet. At the E.N.E. end a bed of crinoidal limestone, probably a continuation of the one seen at the top of the higher section, rests conformably on the quartzose conglomerate which extends vertically below the floor of the quarry. The conglomerate exhibits obscure bedding in parts, some of the beds being lenticular. On the W.S.W. side the conglomerate rests unconformably against limestones dipping about 26 degrees N.W. The field relations suggest that the irregular junction here is original, and that it represents the flank of the channel eroded in these limestones. The precise age of the flanking

[1] Geol. Mag., Vol. LVII, 1920, p. 78.

limestones is not altogether clear; they are later than the Caldon *Humerosus* beds, and are faulted down along with the quartzose conglomerate. They appear to us to represent a portion of the upper part of the *Lonsdalia* subzone, and to be related to the fossiliferous limestones of the churchyard at Cauldon to the north,[1] which are almost certainly upper D_2. The somewhat similar faulted block of fossiliferous limestones opposite the Red Lion Inn, about half a mile south, is probably of the same age.

The horizon of the *Humerosus* beds of Caldon Low has been the subject of some dispute during recent years. In 1908[2] they were tentatively assigned by Dr. Sibly to the upper part of the Lower *Dibunophyllum* zone, D_1. This position received strong confirmation in 1918 by Mr. L. M. Parsons' researches in Leicestershire (at Breedon Cloud and Breedon-on-the-Hill).[3] Other workers, including the late Dr. Wheelton Hind,[4] have definitely assigned them to the base of the Visean, viz. $C\text{-}S_1$. A full discussion of this important problem cannot be entered upon here, but must be reserved for a future paper dealing with the horizon of the *Humerosus* beds of Dove Dale. A preliminary article on this area, by one of the present writers, has already appeared in this Magazine.[5] The Dove Dale limestones are of the "Brachiopod Bed" type, and their faunal characteristics suggest that their stratigraphical horizon is nearer D_2 than D_1. We are inclined to regard the Caldon Low limestones with *Productus humerosus* as a more normal, but less fossiliferous, development of the Dove Dale series. The species at Caldon is not common throughout, but occurs only in well-defined beds, associated with a few other fossils, including two or three interesting forms of corals, which require further study.

Petrography of the Conglomerate.—Want of space prevents a lengthy discussion of the various constituents of the quartzose conglomerate, but readers are referred to the paper published in February, 1919 (op. cit., p. 60), for the main details. The whole assemblage, in our opinion, contains nothing of later date than the Carboniferous Limestone.

As pointed out in the earlier paper (op. cit., pp. 62–3), a rolled-shell and limestone-pebble conglomerate forms a striking feature along the boundary of the Midland Limestone massif on its north-western and western sides. In places this conglomerate contains a fair amount of well-rounded quartz, some pebbles being of large size.[6] From closer study of this marginal feature we have no

[1] Geol. Mag., Vol. LVI, 1919, pp. 61–2.
[2] Quart. Journ. Geol. Soc., vol. lxiv, 1908, p. 44.
[3] Ibid., vol. lxxiii, 1918, pp. 94–100.
[4] Geol. Mag., vol. LV, 1918, p. 480; Vol. LVII, 1920, p. 78.
[5] Ibid., Vol. LVI, 1919, pp. 507–9; see also Sibly, ibid., Vol. LVII, 1920, pp. 20–2.
[6] We have seen specimens in W. F. Holroyd's collection and possess others from similar beds near Wetton, Staffs. See also Trans. Manch. Geol. Soc., vol. xxv, 1896, pp. 124–5.

hesitation in correlating the Caldon quartzose conglomerate with it, and in assigning the whole series to the *Cyathaxonia* subzone D_3. The same horizon is represented by the series of limestones in the small quarries near Field House, north of Waterhouses.[1] In some of the beds here quartz pebbles and grains occur associated with rolled and broken shells, pebbles of limestone, fish-teeth, crinoid debris, and corals (several forms). Some of the brachiopod shells and corals are beekized, and stand out in relief on joint faces. We are also of the opinion that the greater part, if not the whole, of the series of limestones and rolled shell-beds exposed in the quarries at Waterhouses belong to the same horizon, viz. D_3. The shell- and limestone-pebble conglomerate is well seen in the disused quarry north of the station; it contains occasional quartz-pebbles. In this same quarry one of the writers (J. W. J.) has collected a number of interesting corals, including *Michelinia glomerata*, *Favosites parasitica*, and *Alveolites septosa*. The absence of any record of the occurrence of the last-named in the south-western district has been specially remarked upon by Dr. Sibly.[2]

It is not without interest to note that there is strong evidence of earth-movement and erosion in the eastern part of the Midland area in late D_2 times. In a section near Youlgreave, according to Dr. Sibly,[3] black shales of the Pendleside Series clearly overstepped the truncated edges of limestone beds representing a high level in the *Lonsdalia* subzone, D_2. "This section," Dr. Sibly points out, "affords evidence of local earth-movement and erosion, contemporaneous with the deposition, in other parts of the area, of the uppermost beds of the Carboniferous Limestone or the lowest beds of the Pendleside Series." The *Cyathaxonia* Beds, D_3, are absent here, and this may be due either to their removal by denudation during early Pendleside time or to the locality having formed land during *Cyathaxonia* time. Mr. C. B. Wedd[4] has also described a similar example of local unconformity at Darley Dale. It is not improbable that other examples will be found ultimately in the Midland area. The formation of the rolled-shell and limestone-pebble conglomerate (quartzose in part) referred to in this article seems to us to have been the result of the earth-movement and erosion which produced the above-mentioned unconformities.

Conclusions.—The Caldon quartzose conglomerate is a true "Intraformational conglomerate," deposited in D_3 times. It fills an erosion channel in beds of D_2 age at Caldon, these beds, together with the conglomerate, having been subsequently faulted down and

[1] These beds were assigned to D_3 by Sibly in 1908. See Quart. Journ. Geol. Soc., vol. lxiv, 1908, p. 61.

[2] Loc. cit., 1908, p. 48.

[3] Loc. cit., 1908, p. 63 and fig. 5 (p. 62).

[4] Discussion of Dr. Sibly's paper, loc. cit., 1908, p. 84, and Mem. Geol. Surv.: "The Geology of the Northern Part of Derby Coalfield, etc.", London, 1913, p. 35.

thrust along. It is contemporaneous with the other conglomerates overlying D_2 limestones round the north-western and western margins of the Midland Limestone massif. The formation of these conglomerates and the erosion of the Caldon channel appear to have been the result of earth-movement in late, or post, D_2 times, evidence of which is present in the eastern part of the Midland area, near Youlgreave and Darley Dale.

The Metamorphism of the Pre-Cambrian Dolomites of Southern Eyre Peninsula, South Australia.

By C. E. Tilley, B.Sc., A.I.C., Emmanuel College, Cambridge.

(*Concluded from p. 462.*)

(PLATE XI.)

The Calc-magnesian Silicate Rocks of the Hutchison Series.

THE rocks arising from the metamorphism of the more impure dolomitic sediments are calc-magnesian silicate types in which all carbon dioxide has been expelled. In some of the rocks to be described it is clear that superposed on the normal metamorphism there has been a metamorphism by addition of material from the neighbouring magma.

The best exposures of these calc-magnesian silicate rocks are at Sleaford Bay, and they are here closely associated with the dolomites of this area. Fragments of this group have been recognized at Fishery Bay to the south, where they occur as bars in the Flinders gneiss, and they are undoubtedly portions of the Hutchison series engulfed by this intrusion.

The rock-types include Diopside rock, with or without quartz or plagioclase; Diopside–Microcline rocks with scapolite or plagioclase as important accessories. Zoisite, titanite, biotite, and graphite are occasionally important constituents.

(*a*) *Diopside Rock.*

This rock forms a prominent headland on the coast of Sleaford, near Sleaford Mere, and bounding section 14*a*. The interbedded rocks here strike north with a dip of 80 degrees west, to vertical. On the west the diopside rock is bounded by impure diopsidic beds which pass into mica and mica-graphite schists, and on the east it is bounded by garnet gneisses. The whole diopside bed is intimately veined by quartz strings, which traverse it in sill-like fashion. On the transverse joint faces in veins and in vugs there are present well-developed prisms and needles of actinolite.

Under the microscope the rock is seen to consist almost exclusively of a colourless to pale-green pyroxene, with a high extinction angle. It is non-pleochroic, and the individual grains only occasionally show crystallographic boundaries. The rock as seen in hand-specimens is of a pale-green colour, and may vary considerably in texture from place to place. The grain size is, however, usually

FIG. 1.

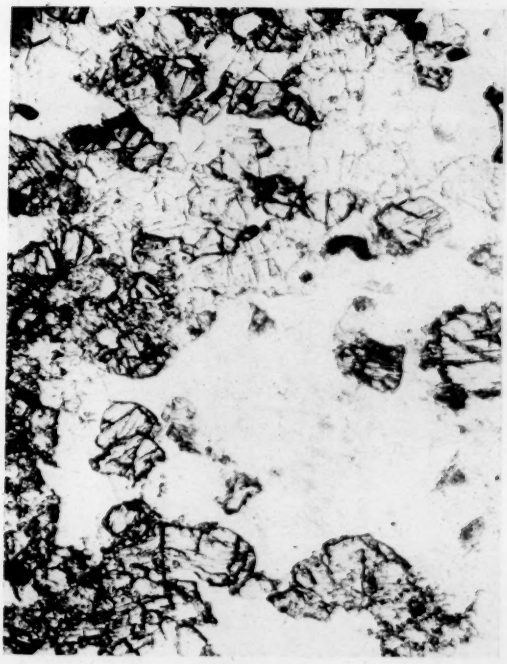


FIG. 2.

medium and of a granular nature. The specific gravity is 3·25. In many cases an incipient alteration to a pleochroic actinolite can be observed in the slides. This may develop peripherally or in isolated spots through the grain. In the associated quartz veinlets flakes of graphite and little rounded grains of diopside are often present. Graphite also occurs along joint faces. The diopside rock occurring as an inclusion in the igneous gneisses of Fishery Bay is essentially similar, but here it has been invaded by the magma in the form of felspar veins.

In these cases the felspar has been very prone to alteration, and in some slides it is represented by its decomposition products as strings through the diopside grains or between and at the corners of these individuals. The original felspar was a plagioclase and had a refractive index greater than C. balsam. In some cases it was as basic as a calcic andesine. Scapolite and zoisite are present in addition to sericite as decomposition products. Hornblende may in some cases be seen as streaks traversing the rock in hand-specimens. Under the microscope an example of this type was seen to consist of diopside and hornblende intergrown without any clear evidence that the amphibole has been derived from it.

A slice cut from a diopside rock developed as a result of the intrusion of a quartz vein in the dolomite of the Waterfall Creek, Hundred of Hutchison, shows greyish diopside, tremolite, and quartz. The rock has been crushed and the tremolite is the result of the crushing of the diopside. The quartz shows undulose extinction, and is in contact with tremolite, this relation being contrary to that expected, if tremolite had arisen as a direct result of silication.

(*b*) *Diopside-Microcline Rocks.*

East of the diopside headland the rocks pass into more aluminous beds, in which diopside is still an important constituent. These rocks have all the appearances of representing a transition into calcareous shales and sandstones from purer dolomitic sediments prior to metamorphism. They are interbedded with rocks that are now garnet gneisses, sometimes carrying sillimanite, and these are probably also metamorphosed sediments.

The diopside-bearing rocks have also suffered intrusion from quartz solutions, as represented by quartz veinlets, and strings traversing them, and these on weathering give the rock quite a serrated appearance. When examined under the microscope these rocks are seen to contain the following silicates, to the exclusion of all carbonate minerals—diopside, microcline, plagioclase, scapolite, biotite, titanite, zoisite, and quartz. Graphite is also usually present in small amount. A typical section is described as under.

No. 160. Diopside is present in light-green coloured grains and often shows crystal outlines. The extinction angles of these diopsides reach a value of 44 degrees, and the light-green colour of the mineral suggests the presence of the hedenbergite molecule

entering the constitution. At the periphery and along cracks or cleavages it is changing to actinolite. The potash felspar is present in considerable amount. The type of extinction is that characteristic of certain microclines in which a submicroscopic twinning is suggested.

Scapolite is plentifully distributed in brilliantly polarizing grains, whose double refraction is greater than ·035, and it has the high refractive index corresponding to a scapolite of the meionite end of the series. It is uniaxial and optically negative. The rectangular cleavages are well developed: they are not pinakoidal cleavages, but prismatic, and the extinction of sections which are not quite basal is in accord with this. This apparently is the case for the scapolites of the Grenville series of Ontario as described by Adams and Barlow.[1] The mineral separates with plagioclase from the rock powder in a bromoform-benzol solution of density 2·72. It dissolves in a mixture of strong hydrochloric and hydrofluoric acids without any effervescence.

In thin section the interference colours are as high as third order greens when the diopside gives second order yellows.

Plagioclase is present in small amount, with the usual twinning lamellæ. Separated from the rock powder, it has a specific gravity greater than 2·72. The refractive index is greater than 1·56, but only a few sections show a R.I. greater than 1·57. β is just under 1·57. Most sections give a negative sign, but a few show positive birefringence. The symmetrical extinctions of albite lamellæ reach 40 degrees. The plagioclase is therefore a bytownite, and positive sections indicate a transition to labradorite. The grains are sometimes bordered by a scapolite fringe, and in other cases the grain is broken up and converted into a confused aggregate of scapolite, with isolated sectors of plagioclase.

The remaining constituents are subordinate in amount. Strongly pleochroic actinolite borders the pyroxene, and in a few cases appears to be intergrown with a small amount of biotite. A mineral regarded as sphene is sparsely distributed through the rock. It is usually in more or less rounded grains of a brown colour. Occasionally, however, traces of prism and pyramid faces can be seen, and in such cases the extinction is distinctly oblique. Pleochroism is often noticeable, the change being from a light to a deeper brown.

The axial angle is not large to judge by the curvature of the isogyres. The birefringence is positive, and a strong axial dispersion is to be observed $\rho > v$.

Graphite is present in spongy and irregular flakes, apatite in prisms and grains embedded in microcline, or associated with scapolite. Quartz is quite localized, and is probably part of a veinlet which cuts the rock.

In another rock (216) plagioclase takes the place of scapolite in the type already described. The plagioclase is of the same

[1] F. D. Adams and A. E. Barlow, Mem. Geol. Surv. Can., No. 6, 1910, p. 102.

composition as in (160), and is undergoing alteration to a sericitic aggregate, potash apparently being derived from neighbouring microcline. Quartz is evenly distributed through the slide. The remaining constituents include zoisite in small amount. This rock formed a portion of a rifted bar of mica schist in a granite sill a few hundred yards to the east of the diopside headland, and is clearly related to the diopside–microcline rocks already described.

Zoisite is plentifully distributed through a rock, otherwise very similar to the type (160) already described. In this rock (123) plagioclase is absent, and its place is taken by clear, colourless grains of meionite. Zoisite is abundant in some parts of the rock, but may disappear in others. This mineral is usually quite irregular in outline, but has a well-developed single cleavage. It is commonly twinned, and the anomalous interference colours are very striking. The plane of the optic axes is at right angles to the cleavage trace, and the extinction is often oblique, angles up to 25 degrees being observed. The sign of the birefringence is positive. These characters agree with the properties of clinozoisite. It is, however, probably not of uniform composition, as judged by the variability of the interference tint seen in one grain. The development of higher interference colours suggests the intergrowth of epidote molecules. Graphite may occur intergrown with the green pyroxene, but it is more characteristically associated with the zoisite, often in irregular bunched aggregates. Quartz is also present.

An interesting rock (106) forms part of the rifted block of mica schist already referred to above. In hand-specimens this rock is characterized by the abundant development of mica, but parallel to the foliation there are developed lenses of green pyroxene and white felspar. The original rock was apparently an aluminous sediment, and contained streaks and lenses of a more calcareous nature. On metamorphism these have developed into diopside-felspar lenses. Examined under the microscope the minerals seen to be present are microcline, diopside, biotite, plagioclase, apatite, and some secondary ragged grains of zoisite.

Diopside is fairly uniformly distributed in colourless grains, with occasional development of uralitic actinolite at the periphery of the grains. Microcline is clear and unaltered, showing the characteristic microcline extinction. Biotite is abundant in flakes, strongly pleochroic in brownish yellow to brown tints, and contains little grains of zircon surrounded by pleochroic haloes.

Water-clear grains of plagioclase felspar are plentifully distributed. The refractive index is considerably greater than C. balsam, and sections showing positive and negative birefringence are present. The extinctions in the symmetrical zone for albite lamellæ, together with the above, indicate a range of composition from labradorite–bytownite to bytownite. Diablastic intergrowths of plagioclase and quartz form bays of myrmekite-like nature into plates of the potash felspar.

The Chemistry of the Development of the Calc-magnesian Silicate Rocks.

We have already referred to the order of development of metamorphic minerals in an impure dolomite. The minerals which first make their appearance are predominantly silicates or aluminates of magnesia, and it is in accordance with this greater chemical activity of MgO that the dominant lime-bearing minerals, as scapolite, plagioclase, etc., are only developed when magnesia has been satisfied.[1] The formation of diopside occurs in the presence of abundant silica, and the occurrence of extensive beds of practically pure diopside is eloquent evidence that the original sediment had the lime-magnesia ratio of a true dolomite. The explanation of the formation of such large masses of diopside rock, however, by metamorphism, without the addition of material, i.e. by residuary crystallization, demands just that amount of silica uniformly distributed through the mass to satisfy the diopside reaction. The conditions yielding such a distribution are, however, not likely to have been attained, and the field evidence strongly favours the view that addition of material in the form of the numerous quartz veins was in part responsible for the diopsidization. The rock as now constituted is to be regarded as a hybrid type, in which silication was partly effected by residuary crystallization and completed by silica solutions from the neighbouring granite, now represented by the numerous quartz veins traversing the diopside rock. Moreover, in the adjoining calc-magnesian silicate rocks, there is abundant evidence of veining of these rocks by quartz strings. For the same reason it is doubtless to the addition of material from the magma, rather than to detrital material present in situ, that we must ascribe the expulsion of the last remnants of carbon dioxide from some of the more aluminous beds.

In the calc-magnesian silicates at Sleaford, and in the Hutchison area, however, there is no reason—with certain exceptions to be referred to below—to invoke the aid of magmatic material other than the purely volatile reagents and silica. The metamorphism, by addition to these rocks, is at most a silication.

In the rifted diopside block in the igneous gneisses of Fishery Bay, the mass is penetrated by felspathic stringers, and this is to be ascribed to the presence of the surrounding fluid magma.

[1] Cordierite would appear to be an exception to this rule. Its absence in metamorphosed limestones is remarkable. A development in accordance with the equation

$$2\,CaMg(CO_3)_2 + 2\,H_4Al_2Si_2O_9 + SiO_2 = (2\,MgO.2\,Al_2O_3.5\,SiO_2) + 2\,CaCO_3 + 2\,CO_2 + 4\,H_2O$$

cordierite

might be expected, but it would appear that the alumina is absorbed in anorthite, and diopside forms instead.

$$CaMg(CO_3)_2 + CaCO_3 + H_4Al_2Si_2O_9 + 2\,SiO_2 = CaMg(SiO_3)_2 + CaAl_2Si_2O_8 + 2\,H_2O + 3\,CO_2$$

The conversion of diopside in the diopside rock into actinolite in vugs, along transverse veins and joints, is paralleled in the pyroxenites (altered limestones) of Ontario as described by Adams and Barlow.[1] It is stated (p. 91), "a deep green hornblende is also seen occasionally running through the pyroxenite in narrow veins, as if it had developed along cracks."

The impurer dolomitic sediments on metamorphism have ultimately been converted into silicate rocks, in which the minerals diopside and microcline are prime constituents. This association of pyroxene and felspar is one of considerable importance, especially when the nature of the detrital minerals in the original sediment is considered. The development of these minerals can be represented by the following equation, in which sericite and quartz are the detrital materials involved:—

(*a*) $CaMg(CO_3)_2 + H_2KAl_3(SiO_4)_3 + 3\,SiO_2 = CaMg(SiO_3)_2 + KAlSi_3O_8 + Al_2SiO_5 + H_2O + 2\,CO_2$

(*b*) $Al_2SiO_5 + CaCO_3 + SiO_2 = CaAl_2Si_2O_8 + CO_2$,

and this doubtless represents the case where the diopside and microcline are intimately associated with plagioclase. How far the reaction has proceeded by absorption of excess alumina in the pyroxene is not evident, thus:—

(*c*) $4\,MgCO_3 + 3\,CaCO_3 + H_2KAl_3(SiO_4)_3 + 7\,SiO_2 = \begin{pmatrix} 3\,CaMg(SiO_3)_2 \\ MgAl_2SiO_6 \end{pmatrix} + KAlSi_3O_8 + 7\,CO_2 + H_2O$,

but the very characteristic association of these two minerals, often to the exclusion of other aluminous types in which excess alumina could be absorbed, would seem to demand this equation.

We have already interpreted the formation of phlogopite in the dolomite marbles as a result of an interaction between dolomite and detrital sericite, or sericite and quartz, and it would appear that with an excess of silica this reaction in turn would be further advanced, the resultant phlogopite giving place to diopside and microcline. Using the minerals of the right-hand side of this equation, we have with excess of silica (*vide* p. 459)—

(*d*) $H_2KMg_3Al(SiO_4)_3 + MgAl_2O_4 + 5\,CaCO_3 + 10\,SiO_2 = 4\,CaMg(SiO_3)_2 + KAlSi_3O_8 + CaAl_2Si_2O_8 + 5\,CO_2 + H_2O$.

Diopside microcline rocks may thus arise by simple residuary crystallization or the metamorphism may possibly take place in two stages. Firstly residuary crystallization may be only sufficient to produce the phlogopite marble stage, and by a later additive metamorphism [2] the silication of this rock to a diopside microcline type. For the rocks under discussion the view that residuary crystallization is solely responsible for the mineralogical changes

[1] Loc. cit. supra, p. 91.

[2] Cf. J. E. Spurr, *Econ. Geol.*, vol. vii, 1912, p. 455. This term would be embraced under V. M. Goldschmidt's term "pneumatolytic contact metamorphism".

involved is in accord with both field and microscopic evidence for the majority of types investigated. Where, however, the rocks are intimately penetrated by quartz strings, complete decarbonation cannot necessarily be inferred, prior to the invasion by silica solutions from the granites, and in view of the variability of composition of sediments of this type it is probable that the expulsion of the last traces of carbonate minerals from some of these types was accomplished by siliceous invasions.

Referring to the equation (*c*), it will be seen that the diopside is shown to contain the Tschermak molecule, and the validity of this equation would be considerably strengthened if it were possible to detect the presence of alumina in these diopsides, apart from the fact that excess alumina may enter anorthite in many cases. The optical characters shed little additional light on this question beyond confirming that a pure diopside is not involved [1] (p. 493).

In the case of detrital biotite being a source of some of the MgO of the pyroxene, there may be no available alumina to be dealt with, thus :—

$$K_2Mg_2Al_2(SiO_4)_3 + 2\,CaCO_3 + 7\,SiO_2 = 2\,CaMg(SiO_3)_2 + 2\,KAlSi_3O_8 + 2\,CO_2.$$

But as in most biotites part of the K is replaced by H, this would not be the general case.

The remaining minerals accompanying the diopside–microcline association call for some remark.

Bytownite is characteristic.

With the utilization of all magnesia from the dolomite molecule residual calcite is free to react with alumina and silica, in the form of sericite or kaolin, and anorthite may thus arise, e.g. :

$$\underset{\text{kaolin}}{CaCO_3 + Al_2O_3\,2\,SiO_2,\,2\,H_2O} = \underset{\text{anorthite}}{CaAl_2Si_2O_8} + 2\,H_2O + CO_2.$$

If sericite be the source of alumina, the potash would yield microcline, and the soda of the sericite could be distributed between the microcline and anorthite. (See also the equations already set down.)

With the dwindling of plagioclase in these rocks, a member of the scapolite group takes its place, and although these two minerals may occur together the rocks are usually characterized by an abundance of one or the other. The scapolite of these rocks has been shown to approximate to meionite in composition.

In view of the recent work of Borgström [2] and Sundius [3] on the constitution of Finnish and other scapolites, in which they show

[1] Diopside microcline rocks have been described by J. S. Flett ("The Geology of the country around Bodmin and St. Austell": Mem. Geol. Surv., 1909, p. 100), and by E. B. Bailey ("The Geology of Ben Nevis and Glen Coe": Mem. Geol. Surv., 1916, pp. 190–4), and the associations in those cases would seem to demand the presence of an aluminous diopside as these investigators have suggested.

[2] L. H. Borgström, Zeitschr. Kryst. Min., vol. liv, 1914, p. 238.

[3] N. Sundius, Bull. Geol. Inst. Univ. Upsala, vol. xvi, 1919, pp. 96–106.

that the dominant meionite molecule is not the oxide type of Tschermak, but of the type $CaCO_3$, $3\ CaAl_2Si_2O_8$, it was of interest to test these scapolites for CO_2.

An uncovered thin section was treated firstly with dilute HCl, and then observed under the microscope. No evolution of gas occurred. More drastic treatment with a mixture of hydrochloric and hydrofluoric acids failed to show evidence of the presence of carbon dioxide. The grains as observed under the microscope slowly dissolved without effervescence.

As far as microscopic tests are available, therefore, there is no evidence to indicate carbon dioxide as an essential constituent of the scapolites of the rocks under discussion. The close similarity in composition between anorthite and meionite, and the conditions under which one or the other is produced in these rocks, are worthy of remark.

It is possible that chlorine of magmatic origin or derived from the sediments themselves may be the determining factor. The suggestion is that, acting catalytically, chlorine may induce the formation of scapolite, which under other conditions would give place to plagioclase. Nor is it, perhaps, essential under these circumstances that scapolite should contain this element in its final constitution.

$$4\ CaCO_3 + 3\ (\underbrace{Al_2O_3,\ 2\ SiO_2,\ 2\ H_2O}_{\text{kaolin}}) = (4\ CaO,\ 3\ Al_2O_3,\ 6\ SiO_2) + \underbrace{(Cl_2)}_{\text{scapolite}}$$
$$6\ H_2O + 4\ CO_2.$$

Titanite, which may be an important constituent, is doubtless derived from the interaction of detrital rutile, calcite, and silica, or the recrystallization of this mineral itself.

Conclusion.

Embraced within the oldest group of sedimentary rocks of Southern Eyre Peninsula—the Hutchison series—is a series of dolomites and calc-magnesian silicate rocks. These rocks represent the metamorphosed equivalents of an original sedimentary series, ranging from true dolomites to types in which silica and alumina were abundant detrital constituents.

The series has been invaded and metamorphosed by the succeeding gneisses of the Flinders series. It is shown that for the dolomites residuary crystallization alone can account for the development of the metamorphic minerals.

For the diopside rock masses there is clear evidence that superposed on the normal residuary crystallization is an additive metamorphism—(contact metasomatism of Barrell, or pneumatolytic contact metamorphism of Goldschmidt)—in the form of silica solutions from the granites, and it is to these that the final diopsidization is due. For the diopside–microcline rocks simple residuary crystallization is adequate, but in some examples it is probable that additive metamorphism is responsible for the removal of the last traces of carbon dioxide. The addition of material—

apart from volatile agents—is limited to silica. Where the diopside masses have been engulfed as inclusions in the igneous gneiss, the rock is traversed by felspathic veins derived from the fluid magma.

The writer wishes to record his indebtedness to Dr. Harker, F.R.S., for encouragement and critical discussion during the progress of these studies.

EXPLANATION OF PLATES IX AND XI.

PLATE IX.

FIG. 1.—Forsterite Marble, Sleaford Bay. The minerals shown are calcite (turbid), dolomite (limpid). The dark grains are forsterite, showing 010 cleavages. Near the centre is a basal section of edenite. Magn. 28 diameters.

FIG. 2.—Forsterite Marble, Sleaford Bay. Constituents: forsterite, with serpentinous decomposition, calcite, dolomite. Twinning lamellæ in dolomite are seen in relation to the rhombohedral cleavages, in the clear grain below on the left. Magn. 28 diameters.

PLATE XI.

FIG. 1.—Diopside Rock, Sleaford Bay. The dark bands are diopside, and the white are quartz veins. The reticulation of the latter is clearly marked.

FIG. 2.—Diopside–Microcline Rock. The clear central area is microcline. In the upper half of the section are basal sections of scapolite showing 110 cleavages at right angles, and diopside. Magn. 28 diameters.

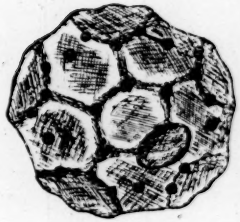
Echinoidea from Western Persia.

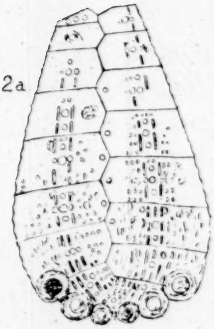
By J. W. GREGORY and ETHEL CURRIE, Geological Department, University, Glasgow.

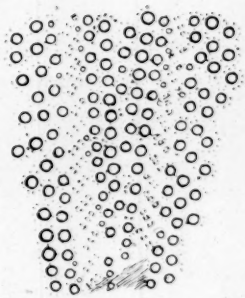
(PLATE XII.)

THE Geological Department of Glasgow University has recently received from Dr. W. R. Smellie and Mr. J. V. Harrison some fossils collected by them which throw further light on the age of the limestones of the Persian arc at the north-western end of Luristan, about 100 miles north-east of Baghdad. The locality, Gilan, is on a tributary of the Diala, about 30 miles south-east of Kasr-i-Shirin, a well-known station on the main road from Baghdad to Teheran. The geology of this part of the Persian frontier has been investigated by J. de Morgan (Miss. Sci. Perse, vol. iii, pt. i, Étud. Géol., 1905, pp. 71–112), who has given a geological map (ibid., pl. xix) of an area about 60 miles south-east of Gilan. De Morgan has identified there a folded series of Cretaceous and Eocene limestones, with lacustrine and gypsiferous Miocene beds. The locality at which the fossils were collected by Messrs. Smellie and Harrison is in line with the strike of the rocks in the area of de Morgan's map.

Dr. Smellie's collection was made at Iman-Hasan, near Gilan, from a limestone on the summit of an anticlinal inlier, which is unconformably covered by limestones referred to the Eocene. The fossils include various echinoids, molluscs, brachiopods, corals, and bryozoa. The echinoids give the best evidence of correlation. His collection includes the following echinoids:—







Del. E. Currie.

CRETACEOUS ECHINOIDEA FROM PERSIA.

1. *Rhabdocidaris morgani* Gauthier, 1902 (Miss. Sci. Perse, vol. iii, pt. iii, p. 145, pl. xx, figs. 3–6). Originally obtained by de Morgan from the Upper Senonian in Luristan; the exact locality of the type has been lost. Dr. Smellie's specimen is a well-preserved segment from the Lower Senonian Limestone. He also collected an uppermost interambulacral plate.

2. *Cidaris husseini* Cotteau & Gauthier, 1895 (ibid., vol. iii, pt. ii, p. 82, pl. xiii, figs. 10–12). This species is based on spines which were obtained by de Morgan at Dèrrè-i-Chahr. Dr. Smellie's collection includes six broken spines.

3. *Salenia cossiæa* Cotteau & Gauthier, 1895 (ibid., p. 83, pl. xiii, figs. 13–19). Specimens obtained by de Morgan at Dèrrè-i-Chahr, Endjir-Kuh, and Aftab.

Dr. Smellie's specimen is small and well preserved; diameter 12 mm., height 8 mm. Its characters are illustrated by Pl. XII, Figs. 1*a* and 1*b*.

4. *Codiopsis smellii* n.sp. (Figs. 2*a–c*.)

Diagnosis.—Test sub-hemispherical; base slightly contracted. Horizontal section almost circular but slightly pentagonal.

Apical disc.—Periproct pentagonal. Each genital plate has a large pore near the outer edge, and a granule near the edge of the periproct. Each ocular plate bears four large granules and lines of small granules.

Ambulacral areas.—Each pore zone includes 27 pairs of small round pores in a straight vertical series except at the base, where the pairs are in arcs and the pores are smaller and closer. Near the peristome each column has a vertical series of three tubercles which become smaller towards the peristome. The rest of the ambulacral area has very few granules; each ambital plate has three granules arranged in a triangle.

Interambulacral areas.—About three times the width of the ambulacral. About eight plates in each column. At the base of each column three large tubercles occur in a transverse row; of these the adambulacral tubercle is the largest. The plates are ornamented by numerous granules, which are elongated vertically and form two parallel vertical broken ridges. Some of the elongated granules are perforated. Between the vertical ridges is a row of round granules, three in each plate; the middle granule is the largest. Some granules have a distinct mamelon; in others the boss consists of a flat topped ring with a central pit. These pitted granules probably bore the "mamelons radioliformes" of Cotteau (Pal. franç., Terr. Crét., Ech., vol. vii, 1866, p. 774). Dimensions:

	Length.	*Breadth.*	*Height.*
No. 3 . .	1·2 mm.	1·2 mm.	7 mm.
No. 4 . .	1·3 mm.	1·25 mm.	7 mm.

Distribution.—Collected by Dr. W. R. Smellie at Iman-Hasan, Lower Senonian Limestone.

Figures.—Fig. 2*a*, an interambulacrum, × 4 dia. Fig. 2*b*, an ambulacrum, × 4 dia. Fig. 2*c*, apical disc, × 4 dia.

Affinities.—*C. lorini* and *C. doma* differ from this species by the absence of the vertical arrangement of the epistroma. In this respect the new species most resembles *C. arnaudi* Cott. (op. cit., 1866, p. 786) from the Lower Senonian of southern France, in which, however, it is less developed. Amongst recently established species *C. texana* Whitney from the Buda Limestone, Texas, 1916 (Bull. Amer. Pal., vol. v, pp. 91–3, pl. xx, fig. 2), described as nearly related to *C. doma*, differs by having more of its lower pores in arcs and its ornamentation of "fine longitudinal undulating ridges". *C. mortenseni* Lambert (Ann. Univ. Lyon, vol. i, fasc. 30, 1911, p. 176, pl. xvi) is more tubercular, having tubercles on the upper as well as on the lower surface. *C. libanoticus* de Lor., 1901 (Notes pour servir Ét. Ech., 1901, p. 27; cf. R. Fourteau, 1913, Bull. Inst. Egypt, vol. vii, p. 57, pl. vi, fig. 6) closely resembles *C. lorini* Cott. var. *alpina*; but Fourteau's figure shows no sign of the vertical epistroma of *C. smellii*.

5. *Pyrina orientalis* Cotteau & Gauthier, 1895 (op. cit., p. 68, pl. xi, figs. 1–8). De Morgan obtained his specimens from Dèrrè-i-Chahr and Endjir-Kuh.

Dr. Smellie's specimen from Gilan has the dimensions—length 24 mm., breadth 20 mm., height 15 mm.

6. *Echinoconus douvillii* Cotteau & Gauthier, 1895 (ibid., p. 70, pl. xi. figs. 9–13). De Morgan's specimens are from Dèrrè-i-Chahr and Aftab.

Dr. Smellie collected two specimens (Nos. 5 and 6):—

	Length.	*Breadth.*	*Height.*
No. 5 . .	27 mm.	24 mm.	19 mm.
No. 6 . .	25 mm.	22 mm.	16 mm.

No. 5 shows well the arrangement of the pores near the peristome in oblique triplets (Fig. 3).

7. *Hemiaster parthicus* Gauthier, 1902 (ibid., p. 137, pl. xx, figs. 1 and 2). De Morgan's specimen was obtained in Luristan; the exact locality is unknown.

In Dr. Smellie's specimen (No. 6*d*) the dorsal keel is broken, and the apical disc is hidden by the interambulacral areas which have been pressed over it.

Dimensions.—Length 28 mm., breadth 27 mm., height 18 mm.

Dr. Smellie has sent with the echinoids a few molluscs which include some young oysters, the *Lopha morgani* Douvillé. The brachiopoda include *Terebratula brossardi* Th. & Pér.

The age of this fauna is unquestionably Senonian, and apparently Campanian. It corresponds with the fauna of the "echinoid limestone" of de Morgan, who placed it in the Mastrichtian, but at the base of that division. The evidence of the echinoids is in favour of the horizon being pre-Mastrichtian, but still Senonian.

The second fauna was collected by Mr. J. V. Harrison in the same district, at the locality of Tang Diarah, near Gilan. The fossils include some echinoids, most of which have been rather distorted.

The collection includes the following species:—

1. *Schizaster vicinalis* Agassiz & Desor, 1847; Gauthier, 1902 (op. cit., p. 172, pl. xxiii, fig. 4). Obtained by de Morgan from the Upper Eocene at Mollah Ghiavan. Mr. Harrison's specimen is from the Upper Eocene at Tang Diarah. It is somewhat distorted.

Dimensions.—Length 48 mm., breadth 44 mm., height 25 mm.

2. *Schizaster rimosus* Desor, 1847; Gauthier, 1902 (ibid., p. 174, pl. xxiii, fig. 5). De Morgan's specimens are from the Upper Eocene at Mollah Ghiavan.

Mr. Harrison's specimen from Tang Diarah is poorly preserved. This species resembles *S. vicinalis* in many ways. It is distinguished therefrom by its unpaired and paired anterior ambulacral grooves being narrower, and by the posterior petals being relatively a little longer.

3. *Ditremaster nux* (Desor), 1853; Gauthier, 1902 (op. cit., p. 164, pl. xxi, figs. 9–11). De Morgan collected many specimens from the Upper Eocene at Mollah Ghiavan. Mr. Harrison's specimens from Tang Diarah have the following dimensions:—

	Length.	*Breadth.*	*Height.*
H_3 . . .	24 mm.	22 mm.	19 mm.
H_4 . . .	27 mm.	23 mm.	21 mm.
H_7 . . .	15 mm.	13 mm.	11 mm.

These dimensions do not agree with those of de Morgan's specimens which are as broad as they are long; but Mr. Harrison's specimens are somewhat crushed. They may belong to the oval variety of *D. nux* mentioned in Pal. franç., Terr. tert., vol. i, p. 422.

4. *Euspatangus ghiavanensis* Gauthier, 1902 (op. cit., p. 156, pl. xxi, figs. 1 and 2). This species was originally obtained by de Morgan from the Upper Eocene at Mollah Ghiavan. Mr. Harrison's specimens are from Tang Diarah. Dimensions:—

	Length.	*Breadth.*	*Height.*
H_{12} . . .	30 mm.	26 mm.	13 mm.
H_{13} . . .	22 mm.	20 mm.	10 mm.
H_8 . . .	24 mm.	21 mm.	10 mm.

The age of this fauna is unquestionably Upper Eocene. Some Middle Eocene echinoids are known from the Pusht-i-Kuh area, but none of those Middle Eocene species is present in Mr. Harrison's collection.

The Iron Ore Supplies of the World.

By F. H. Hatch, M.Inst.C.E., Past-President Inst. Min. Met.

The following article originally appeared in the special "Iron and Steel" number of the *Times* Trade Supplement on July 21 last. It is here reprinted, with some small additions, by the courtesy of the proprietors of that journal.

WITHIN the limits of a brief article such as this must necessarily be, it is impossible to do more than indicate the chief sources of iron-ore supply. The subject is a big one, and of great importance, not only to the British ironmaster, but also to every inhabitant of this country. I am therefore pleased to be able to state that the Federation of Iron and Steel Manufacturers has not only asked the Imperial Mineral Resources Bureau to prepare a summary of the existing information as to the iron-ore supplies of the world, but is also assisting to finance the inquiry. This will mean a more complete survey than is possible to-day.

Any attempt to estimate the world's iron-ore resources is complicated both by the diversity of the products manufactured from the raw material and by the numerous factors which go to connote a commercial iron-ore. Among these the iron content, the presence of beneficial or deleterious constituents, physical condition, geographical position, and means of transportation are all considerations of the first importance.

First consider the iron-content. According to the estimate of the American geologist, Clarke, the crust of the earth contains 4·4 per cent of metallic iron, of which but a very minute fraction has been sufficiently concentrated by geological agencies to form commercially available iron-ores: for one ton of these that contains 60 per cent of iron there are very many tons that contain 50 per cent; while for one ton that contains 40 per cent there are vastly more that contain 30 per cent, and so on. The amount of reserves in an iron-ore field can, therefore, be indefinitely increased by lowering the grade of the material to be included.

With regard to the presence of beneficial or of deleterious constituents, what is prejudicial in one case is beneficial in another. The requirements of the smelters are decisive on this head. If hæmatite pig iron for the acid process of steel-making is required, phosphorus is barred; if, on the other hand, the iron is destined for the basic process, phosphorus is a desideratum. Titanium rules out vast bodies of ore containing a high percentage of iron, because the presence of titanic acid in any notable proportion raises the temperature of fusion and leads to greater fuel consumption and a heavier blast. A small quantity of manganese, on the other hand, is beneficial, since it helps to get rid of sulphur. A high silica-content is an objection, because of the limestone that has to be added to the charge to neutralize the acid constituent, thereby reducing the output per furnace and increasing the cost per ton of pig; but a calcareous ore is sought after, since it is either self-fluxing or can,

if the lime is present in excess, be mixed with siliceous ores in the proportion required for a fusible charge. A self-fluxing ore containing 25 per cent of iron may be as valuable as, or even more valuable than, a refractory ore containing 35 or 40 per cent. Therein lies the virtue of the calcareous ores of Frodingham in North Lincolnshire.

The physical condition of the ore is of the highest importance. If the ore is friable, disintegrates during transportation, and arrives at the smelting works in a dusty condition, or "decrepitates" when heated, it chokes the furnace, prevents the free passage of the gases, and leads to dust losses. Although friable ores can be improved by sintering or nodulizing, this can only be done at the expense of a heavy increase in the cost of production. On the other hand, a hard, dense ore, such as certain classes of magnetite, is refractory, and consequently not looked upon with favour by the ironmaster, except for enriching purposes.

The position of an iron-ore field in regard to the smelting centre has the greatest influence of the utility of the ore. An ore may be desirable in all other respects, but inaccessibility may prevent its use. A notorious case is Brazil, where vast deposits of the best class of iron-ores remain unworked because of their unfavourable geographical position.

The first attempt at a census of the iron-ore resources of the world was an inquiry made upon the initiative of the Executive Committee of the International Geological Congress, which met in Stockholm in 1910, and based on the returns obtained from official and non-official geologists all over the world. A summary of the returns from the five continents made by H. Sjögren showed that the actual known reserves of the world amounted to 22,400 million tons, of which the equivalent iron was estimated to be just over 10,000 million tons, or, at the then rate of pig-iron production of 60 million tons per annum, insufficient to last for 200 years, without allowing for any increase in consumption. Since 1910 the extension of knowledge by exploratory and development work has led to repeated revisions of Sjögren's figures.

The principal known iron-ore reserves of the world are those of the Eastern United States, Newfoundland, Cuba, Brazil, Lapland, Spain and the north coast of Africa, the Central European orefield, and the United Kingdom. There are probably also considerable reserves in India, South Africa, Australia, and Canada.

United Kingdom.

Of the 15 million tons of iron-ore produced in 1918 in the United Kingdom, 80 per cent consisted of Jurassic ironstones, 10 per cent of West Coast low-phosphorus hæmatite, 8 per cent, of Coal Measure ironstone, and 2 per cent came from miscellaneous sources.

An estimate of reserves was made by the Geological Survey in 1917. Taking the Jurassic ironstones first, the following are the tonnages arrived at for "reserves partially developed", under the

headings of ore to be got (1) by open-cast work and (2) by underground mining, from which I have made a deduction for the ore won during the years 1917–19.

	Open-cast, million tons.	Mining, million tons.	Total, million tons.
Cleveland Main Seam . . . North Yorkshire.		177	177
Marlstone . . . . . Lincolnshire, Leicestershire, Oxfordshire, and Warwickshire.	94		94
Frodingham Bed . . . . . North Lincolnshire.	154	336	490
Northampton Bed . . . . . Northamptonshire, Huntingdonshire, Rutlandshire, and Lincolnshire.	1,344	539	1,883
Total . . .	1,592	1,052	2,644

In addition, 26 million tons are assigned to the Westbury (Corallian) ironstone, and 10 million to the Raasay ironstone, neither of which are at present being worked as a source of iron. This brings the total for the Jurassic ironstones to 2,680 million. It is not claimed that these figures are estimates of actually merchantable ore. It is possible that much of the low-grade ore that it is now found profitable to work in open quarries will not constitute an economic proposition when mining has to be resorted to.

The reserves of clay-ironstones and blackband ironstones in the Carboniferous strata of England and Wales are estimated by the Survey at 1,057 million tons. The Scotch Coalfields are estimated to have a reserve of 93 million tons of ironstone, making 1,150 million tons in all. Much is included that in all probability will never be mined. The richer and thicker seams of blackband have long since been worked out, and the present output comes mainly from North Staffordshire and Scotland. In 1918 out of a total output of 1,120,000 tons of Coal Measure ironstone, 1,052,000 tons came from those districts. The clay-ironstones, too, are not worked systematically except in a few places; in many collieries the clayband ribs are only taken down in "brushing" the roads, and in the case of a ball-ironstone the balls are put aside as they occur during the working of the coal, or fireclay, as the case may be, and marketed when a sufficient quantity has accumulated. The output of Coal Measure ironstone, which amounted to over 6 million tons per annum in the 'seventies, has been falling for many years, and is now little over a million tons per annum. The Director of the Survey, in an introduction to the Memoir on the Carboniferous Bedded Ores, states his belief that under present conditions only about half the amount estimated would be available, and in the Memoir dealing with the iron-ores of Scotland a 30 per cent deduction

for losses in mining is suggested. For the present purpose a round 50 per cent of the total given for areas partially developed is taken, which brings the total reserves for Coal Measure ironstone down to 575 million tons of ore of about 30 per cent grade.

In all, therefore, the low-grade ores of the United Kingdom are estimated at 3,219 million, or, say, in round figures 3,000 million tons of 30 per cent ore.

The reserves of low-phosphorus hæmatite of Cumberland and Lancashire are estimated by the Survey at 40 million tons. The grade may be taken at 50 per cent.

Spain and North Africa.

Spain has in the past been the principal source of supply for the high-grade low-phosphorus ores used in European furnaces. The production reached 10 million tons in 1913; but it fell to about half that amount during the War. For many years British makers of hæmatite pig for Bessemer and Siemens Martin steelworks have derived the greater proportion of their ores from Bilbao (some 2½ million tons per annum); but three-quarters of the workable ore has already been mined, and for some time there has been a gradual deterioration in quality due to the exhaustion of the richer mines.

The low-phosphorus ores of Bilbao consist of *vena*, *campanil*, *rubio* (all three varieties of hæmatite), and *spathic* (the carbonate); but the qualities now exported are practically confined to "rubio" and calcined "spathic". The standard guarantee for "best rubio" is 50 per cent iron, 8 per cent silica, and under ·02 phosphorus, but many shipments run about 47 per cent iron, 10 per cent silica, and ·025 phosphorus. The guarantee for "best calcined spathic" is 56 per cent iron, but on account of fuel scarcity cargoes of about 54½ per cent iron and 9½ per cent silica are delivered. Among other ores imported are the Santander washed granular ores, but these, being higher in phosphorus, can only be used in combination with a considerable proportion of other purer ores. Rubio ore is also worked at Castro (Dicido) in Santander, and considerable reserves of low-phosphorus and low-silica ore with iron 47 per cent exist in Almeria (Alquife). A large quantity of ore is mined in Seville and Teruel (Sagunto). Deposits of hæmatite, magnetite, brown ore, and carbonate are also known in the following provinces: Guipuzcoa, Oviedo, Leon, Lugo, Malaga, and Granada; but they have not been much developed and the extent to which they will be worked in the future depends on the results of investigation and the provision of adequate transport facilities. Few of the ores are equal in quality to those of Bilbao.

The Stockholm estimate for the actual reserves of Spain, brought up to date by the Imperial Mining Resources Bureau, is 650 million tons, of which 28 million is credited to Bilbao.

High-grade ores (averaging about 50 per cent iron) are found on

the north coast of Africa in various parts of the Atlas Mountains in Algeria, Tunis, and Morocco; in large part they are of Bessemer grade. The production of these fields amounted in 1913 to close on 2 million tons, of which three-quarters of a million went to England. The principal producers are Benisaf, Zaccar, and Timezrit in Algeria, Djerissa in Tunis, and Riff in Morocco. It is estimated that the output can be increased by half a million tons or more a year by completing the railway from the port of Bona to the Ouenza and Bou Kadra mines, which are in Algeria near the Tunisian border, and about 120 kilometres from the coast. The reserves for North Africa have been estimated at from 100 to 150 million tons.

Scandinavia.

Swedish iron has long been celebrated for its purity and general excellence. The low-phosphorus ore used in its manufacture is in the main magnetite, and comes from a number of old mines in southern Sweden, among which may be mentioned the celebrated Dannemora and Persberg mines. It is smelted locally with charcoal and the reserves are comparatively small. In central Sweden there are some large hæmatite deposits, as, for example, those of Grängesberg and Norberg, which yield ore averaging 60 per cent iron and high in phosphorus. The reserves are estimated at about 100 million tons.

The main resources of Sweden are in Lappland. Great deposits of iron-ore occur there, mainly magnetite and, as a rule, high in phosphorus, although a trifling proportion is of acid Bessemer grade. The largest and most celebrated ore bodies are those of Kiirunavaara and Gellivare, the former (together with Luossavaara) being credited with a reserve of 738 million tons, and the latter (including Kokullskulle) with 265 million. Both ore-bodies were formerly worked on the open-cast system, but underground mining has recently been substituted at Gellivare. They are owned by the Trafikaktiebolag Grängesberg-Oxelösund of Stockholm, and the ores are sold by this Company on a basis of 60 per cent iron, as received, the following grades being distinguished by the phosphorus content:—

Grade.	Phosphorus, per cent.
C^1	Not more than 0·6.
C^2	Not more than 1·0.
D	Over 1·0 and not more than 2·0.
G	Over 2·0.

The output is limited by law to 1,300,000 tons per annum for Gellivare, and 5 million per annum for Kiruna.

The shipping ports are Narvik, on the Atlantic coast, and Luleå, on the Baltic. The former is open all the year round. Before the War

80 per cent of the output went to Germany, but in 1916 a contract was made with the Swedish Government which secured for the United Kingdom approximately 50 per cent of the output.

In Norway the deposits, although large, are of low grade, and require concentration. The present production is small. The most important is that at Sydvaranger, on the northern coast, the shipping port, Kirkenes, on the south side of Varanger Fjord, being within the Arctic Circle. The ore is a low-phosphorus magnetite, occurring in close association with apatite and interbedded with quartz. The bulk of it averages from 30 to 35 per cent iron, and is worked open-cast; but a smaller quantity of 50 per cent ore is mined. To free the ore from apatite a magnetic concentration plant is used, yielding a product which, when briquetted, contains 65 per cent iron and ·02 phosphorus. The reserves are estimated at 100 million tons raw ore. At Dunderland, on the west coast, there is a large deposit of mixed hæmatite and magnetite in association with apatite, the raw ore averaging about 35 per cent iron with a high phosphorus content. By special methods of concentration it is stated that the magnetite and hæmatite can be separated, and the grade of the ore brought up to 68 per cent iron, with only ·03 per cent phosphorus. The reserves are estimated at 150 million tons.

The estimate of the Scandinavian reserves as a whole made by the Swedish geologists for the Stockholm Report, but as revised and brought up to date by the Imperial Mineral Resources Bureau, is as follows:—

	Million tons.	Average iron content, per cent.
Northern Sweden .	1,003	60
Central and Southern Sweden . . .	116	57
Norway . . .	350	35
Total . .	1,469	

Say, 1,500 million tons of 54 per cent grade.

Central Europe.

The "minette" orefield, which extends over a portion of Alsace-Lorraine, Luxemburg, and Belgium, is the most important, in regard to quantity, in Europe, and the struggle for its possession was one of the main causes of the late War. The annexation in 1871 of the eastern part of the field gave Germany the means of building up a great iron trade, while the early occupation of the Briey and Longwy basins proved a severe handicap to France during the progress of the War. This field in 1912 produced 44 million tons or 28 per cent of the world's output, divided between Germany, Luxemburg, and

France. The ore—geologically a bedded oolitic ironstone of Jurassic age—is a carbonate, partly oxidized to brown ore, containing from 27 to 36 per cent iron, as mined, with an average of 10 per cent moisture. The ores are in part siliceous, in part calcareous, and good smelting charges can be obtained by mixing these two varieties in suitable proportions. A valuable feature is the high-phosphorus content, permitting the manufacture of a basic pig containing from 1·7 to 1·9 per cent phosphorus, and suitable for the basic Bessemer or Thomas process. In the greater portion of the field only one bed (the "grey bed") is worked; but its thickness varies from 6 to 20 feet and the reserves are very large, being generally put down at about 5,000 million tons.

Besides the minette ores, France possesses in Normandy, Anjou, and Brittany, oolitic bedded ores of Ordovician age. These occur in a number of detached synclines either as carbonate or hæmatite. The ores (calcined in the case of the carbonate) average from 45 to 48 per cent iron, 10 to 20 per cent silica, and 0·4 to 0·8 per cent phosphorus. They are smelted to basic iron at the Mondeville works, near Caën, for the Normandy deposits, and at the Trignac works, near St. Nazaire, for the Brittany and Anjou deposits. The reserves are estimated to be about 200 million tons.

With the cession of Alsace-Lorraine, Germany lost its biggest orefield, but it retains a number of smaller producing districts, the reserves of which amount to some 1,300 million tons.

United States.

Lake Superior produces four-fifths of the iron-ore output of the United States. (In 1918 it was 86 per cent of a total of 70 million tons.) The ore is derived from a series of ranges in Minnesota, Wisconsin, and Michigan, respectively known as the Mesabi, the Marquette, the Menominee, the Gogebic, the Vermilion, and the Cuyuna, the order given being that of the importance of the annual production. At first all the ore was obtained from open-workings by steam-shovel and other forms of mechanical excavator, and was shipped without further treatment. Mining is, however, becoming more and more necessary, and in places water-concentration, and even calcining, are being introduced in order to raise the iron content and diminish the silica and sulphur. The ore is in the main a hæmatite, but in part is hydrated. Magnetite is only found in the Marquette range and in small proportion. The average iron content of the ore mined is diminishing, having fallen from 56·2 per cent in 1902 to 52 per cent in 1912. The phosphorus content, too, is increasing, the percentage of Bessemer ore having fallen from 64·9 in 1902 to 42·9 in 1912.

From the iron ranges the ore is railed to the shipping ports of Duluth, Ashland, Marquette, and other ports at the western end of Lake Superior, and from there shipped by water to be smelted in Chicago, on the shore of Lake Michigan, or at Cleveland and Buffalo

on Lake Erie. The bulk of it, however, is passed on by rail to Pittsburg and other industrial centres of Pennsylvania and Ohio, the total distance by water and rail to Pittsburg being about 1,200 miles, and thus greater than that of the iron mines of Spain and Scandinavia from British or German furnaces. Cheap water transportation on the Great Lakes has made this possible. The ore-ships are loaded direct from the ore-trains at the rate of 10,000 tons in half an hour, and discharged at the receiving dock in less than half a day. In 1913 the rate for water transport and unloading averaged less than ·07 of a cent, or (at normal exchange) ·035 of a penny per ton-mile. Although navigation is closed for about five months in the year, and a stock pile of 25 million tons has to be accumulated at the loading end, over 60 million tons a year are conveyed in this manner, and by the end of 1918 the Lake District had marketed no less than 900 million tons of ore.

A recent estimate of the available reserves at Lake Superior is 2,750 million tons of an average grade of 52 per cent iron (*Mineral Industry*, 1918).

The red or Clinton hæmatites are bedded oolitic ores of Silurian age cropping out on the eastern flank of the coalfield from Maryland through Virginia and Tennessee to Georgia and Alabama. They reach their highest economic development in the Birmingham district of Alabama, although they are also worked in Georgia and Tennessee, and to a small extent in Virginia. Although the Clinton ores as a whole are rather high in silica, this is to a considerable extent offset by the presence of a good proportion of lime carbonate. Including the Brown Ores worked in the Appalachian Valley and in Tennessee, these south-eastern states had, up to 1918, produced 10 per cent of the whole iron-ore output of the United States. The available reserves are estimated at 1,750 million tons of 36 per cent grade phosphoric ore.

The north-eastern states (New York and New Jersey and Pennsylvania), contribute 1 per cent of the total iron-ore output of the United States. The ores are derived from magnetite mines in the Adirondack region of New York, from Clinton ores in Pennsylvania, and from Brown Ore in Northern New Jersey. In the main they are phosphoric ore, and are used locally. The undeveloped reserves, with an average grade of 35 per cent iron, are estimated at 2,500 million tons.

The following table gives in parallel columns the most recent estimates and those made for the Stockholm Geological Congress :—

Stockholm.	Million tons.	Recent Estimates. (*Mineral Industry*, 1918.)	Million tons.
Lake Superior	3,500	Lake Superior	2,750
Clinton Ores	505·3	S.E. States (Clinton, etc.)	1,750
Miscellaneous	252·5	N.E. States	2,500
	4,257·8		7,000

It will be seen that in comparison with recent estimates, the Stockholm report over-estimated the Lake Superior area, but did not attribute sufficient importance to the remaining areas. Neither estimate includes any of the very low-grade red or Clinton ores, or of the low-grade siliceous ores of the Lake District, of both of which there are enormous quantities.

Brazil.

One of the greatest ore reserves of the world, and certainly the greatest reserve of ore suitable for the acid Bessemer process, is situated in the province of Minas Geraes, in Brazil.

The ores are hæmatite and magnetite, and occur in rocks similar to the banded jasper of North America and South Africa. They vary in grade, but the average iron content is over 60 per cent, and the phosphorus is in the main well below the Bessemer limit. A proportion of the ore occurs in thin lamellæ between siliceous layers, but there are large masses of practically pure oxide, like that of Iron Ore Peak (Itabira do Campo) and the Caué deposit of Itabira do Matto Dentro, which is estimated to contain 80 million tons of the highest quality ore. E. C. Harder states that the largest deposit contains at least 350 million tons, and that there are numerous ore-bodies of from 10 to 50 million tons. Their possible aggregate tonnage is enormous, but with the present means of transportation the greater portion is inaccessible. Before the War capital was being found to develop these fields and to provide transportation, and it cannot be long before such valuable deposits will be utilized in the world's markets. The ore will probably be exported in great quantity to British and American Bessemer furnaces.

The economically important ores of Minas Geraes are usually divided into (*a*) *Bedded or Quarry Ores*, consisting of (1) thick bedded massive hematite, and (2) thinly bedded siliceous hematite ("jacutinga"); (*b*) *Fragmental Ores*, consisting of (1) rubble ore (a denudation product of the bedded ores), and (2) Canga (recemented rubble).

The massive ore beds vary in thickness from less than a foot to more than 300 feet, but they are less extensive than the jacutinga ores. Leith and Harder state that single lenses of jacutinga are known more than 3 miles in length and up to 2,000 feet in thickness. Of the high grade massive hæmatite and jacutinga, ranging in iron content from 63 to 69 per cent, the tonnage was stated by Leith, in 1911, to be probably not far short of the total reserves of the Lake Superior district available at that date. The Canga and rubble ores are of lower grade; even these probably average 50 per cent in iron, but the phosphorus is higher than in the bedded ores.

Estimates of the total available reserves in the Minas Geraes field vary from the conservative estimate of 2,000 million tons made by Dr. Derby for the Stockholm Report, up to recent estimates of 3,500 millions. For the whole iron ore region of Brazil, Merriam

and Leith estimate the potential reserves at 7,500 million tons of ore; while *Mineral Industry* (1918) credits Brazil with 5,000 million tons of 63 per cent grade. With regard to the phosphorus content it must be borne in mind that while the quantity of Bessemer ore is very great, in all probability exploration will show that a proportion of the ore is above the Bessemer limit.

Cuba.

The Stockholm estimate for Cuba was 1,903 million tons. More recent estimates agree in placing the reserves at from 2,500 to 3,000 million tons of crude ore (36 per cent iron) for the lateritic blanket deposits of the north coast. There are three distinct ore-fields, namely, those of the districts of Mayari, Moa, and Levisa, of which Mayari is the only one worked at present. The soft, clayey ore is removed by mechanical excavators to an average depth of 19 feet, and there is no overburden. Since it contains from 20 to 30 per cent of moisture, and about 13 per cent of combined water, it is calcined in nodulizing kilns before being shipped to Sparrows Point and Steelton, in the United States, losing thereby one-third of its weight. According to Weld, the nodulized ore averages 55 per cent iron, 4·50 per cent silica, 13 per cent alumina, 1 per cent nickel, and 2 per cent chromium; phosphorus is below the Bessemer limit, and sulphur is negligible. Mixed with other iron, the pig produced from these ores is used for making chilled castings; but the bulk of it goes to make steel for rails, truck-bolts, and all sorts of motor-car parts. The steel is stated to contain from 1 to 1·5 per cent of nickel, and from 0·2 to 0·7 per cent of chromium, with sulphur and phosphorus below 0·04 per cent.

Newfoundland.

No exact estimate of the iron resources of Newfoundland is possible, since, with the exception of a small area where the ore beds outcrop on Bell Island, the whole of this field is under Conception Bay. The ore is a dense bedded hæmatite, averaging over 50 per cent iron, 0·8 per cent phosphorus, and about 10 per cent silica, and therefore suited for the basic process. It occurs in three workable beds of an aggregate thickness of 30 feet, in a trough of Ordovician rocks, which, dipping at a low angle from the outcrop on Bell Island, passes under the sea.

The Wabana mines on Bell Island are operated by the Nova Scotia Iron and Coal Co. and the Dominion Iron and Steel Co., the former company working the upper beds and the latter company the lower bed. The combined output averages about 700,000 tons per annum. The Nova Scotia Co. has recently completed two inclined shafts, by means of which 12,000 tons a day is being raised from workings 2 miles to the dip under the sea. The whole enterprise has recently been merged in the Empire Steel Corporation, in which both British and Canadian capital participate.

The amount of ore ultimately to be recoverable will depend on the engineering skill that can be brought to bear on the problems of ventilation and pumping that such extensive submarine mining will present. E. C. Eckel estimates the economically workable ore at 3,500 million tons of 50 per cent ore within a radius of 5 miles of Bell Island. Newfoundland was credited with 3,635 million tons in the Stockholm Report.

Canada.

Very little is known regarding the iron resources of the Dominion. Of the $1\frac{3}{4}$ million tons of iron-ore smelted in Canadian blast-furnaces in 1919, only 5 per cent was of domestic origin, the balance coming from Lake Superior mines in the United States and from the Wabana mines of Newfoundland. The domestic ores are sedimentary hæmatite ores from Nova Scotia, magnetite from New Brunswick, Eastern Ontario, Quebec, and Texada Island, in British Columbia, and spathic ore from the Michipicoten district of Ontario. The carbonate ore at the Magpie mine, worked by the Algoma Steel Corporation in the latter district, averages 34 per cent iron for the raw stone, and 50 per cent for the calcined material. The low-grade magnetite deposits worked by the Moose Mountain Company at Sellwood, in Ontario, average 34 per cent iron, but the briquetted concentrates run as high as 63 per cent.

The total reserves of the Dominion have been estimated at only 150 million tons, but with the vast unexplored country in Northern Canada it is hard to believe that big reserves will not some day be discovered.

South and West Africa.

Iron-ore of various types are known to exist in South and West Africa. Lateritic deposits similar to those of Cuba, and characterized by a rather high silica and alumina content and small percentages of nickel, chromium, manganese, etc., are common in many parts of the country. One in French West Africa has recently been found to have a reserve of 100 million tons, and to yield a nodulized product running over 60 per cent iron. Hæmatite-magnetite deposits associated with Pre-Cambrian rocks occur over large areas; but they are generally too interlaminated with siliceous material to be workable. This type, however, is stated to be of economic importance in Rhodesia. In the Transvaal there are extensive deposits of low-grade phosphoric ores in the Pretoria Beds, near Pretoria, and at Boskop, near Potchefstroom, which can be used as mixing ores; but the most valuable deposit yet discovered is a high-grade low-phosphorus hæmatite with over 60 per cent iron, occurring at Kromdraai, 45 miles north-east of Pretoria, which it is proposed to mix with the lower-grade phosphoric ores of Boskop for the manufacture of basic pig at Vereeniging.

With the existing data no estimate as to reserves can be made, but it appears certain that large tonnages of iron-ore are available

in the Transvaal, from which suitable mixtures for smelting to basic pig can be made.

India.

The following particulars with regard to India are taken from a note kindly prepared for me by Dr. Coggin Brown, of the Indian Geological Survey.

Important deposits of high-grade iron-ore, mainly hæmatite, associated with banded jasper, and in this respect similar to those of Lake Superior and Brazil, have recently been opened up in India. The best-known deposits are those of Mayurbhanj and Singhbhum, in Bihar and Orissa; Chanda and Drug in the Central Provinces; Kadur in Mysore; and Goa. The Mayurbhanj deposits are being worked by the Tata Iron and Steel Company at Gurumaishini, where a lens of hæmatite has been proved to contain 15 million tons for every 10 feet of depth. This ore averages over 60 per cent iron, manganese 0·8, sulphur 0·01, and phosphorus 0·09. The basic pig made from this ore at the Tata Ironworks, which are situated within 40 miles of the mine workings, contains about 0·04 per cent phosphorus, under 0·05 sulphur, and less than 1 per cent silicon. Similar ore bodies are known at Okampad and Badampahar.

The Singhbhum deposit is being worked at Pansira Hill and Budu Hill, south-east of Manharpur, on the Bengal-Nagpur Railway. It appears to be a part of an iron-ore range forming a definite horizon in the Dharwar rocks, and extending for some 40 miles in a south-westerly direction from Singhbhum. Enormous quantities of ore are believed to exist, but until the supposed extensions have been definitely proved in depth by drilling, no estimate as to quantity can be made.

In the Chanda and Drug districts of the Central Provinces, deposits of high-grade low-phosphorus ore have been discovered, but have as yet not been extensively prospected. The Mysore ores are not of great extent. They are being worked tentatively by the Tata Iron and Steel Company, for the Mysore Government. High-grade low-phosphorus ores exist in Goa and Ratnagiri, probably in considerable quantity; but they have not as yet been proved in depth.

Altogether the reserves of high-grade ore already partly proved in India may be safely put at several hundred million tons, and the prospects are favourable for the existence of very much larger quantities.

Australia.

Little is known of the iron-ore resources of Australia except that many important deposits exist both near the coast and in the interior. Some of these are at present being investigated in South Australia, Western Australia, Queensland, and Victoria.

A high-grade ore is being worked in South Australia by the Broken Hill Proprietary Company at Iron Knob. The ore is carried

at low cost by water transportation to the Company's ironworks at Port Waratah near Newcastle in New South Wales, where it is smelted to basic pig for open-hearth steel manufacture. Work at Iron Knob is at present restricted to quarrying, and the output is about 300,000 tons per annum. No figures as to reserves are available.

Conclusions.

Summarizing the estimates for the great ore-fields of Europe and the Americas (namely, the United States, Cuba, Newfoundland, Brazil, Scandinavia, Central Europe, the United Kingdom, Spain, and North Africa) we arrive at the following round figures:—

	Million tons.
High-grade low-phosphorus ore	6,740
High-grade phosphoric ores	6,460
Low-grade ores	17,100
Total	30,300

Another 1,500 million should be added for the small ore-fields of Russia, Austria, and Greece in Europe, and Chile, Venezuela, Mexico, and Canada in America, making a grand total for the two continents of 31,800 million tons, of which the equivalent iron is 14,310 million tons, or, on the basis of a pig-iron production of 70 million tons a year, sufficient to last over 200 years.

The resources of the continents of Africa, Asia, and Australia are unknown, but it has been shown in the foregoing that important deposits exist in South Africa, Australia, and India, and others are known, for instance, in China, Korea, and Japan. Moreover, having regard to the very large unexplored areas of these continents the existence of great reserves as yet undiscovered is very probable.

An ingenious method suggested by Sjögren and used by Eckel enables the iron-ore resources of the unknown continents of Africa, Asia, and Australia to be roughly estimated on the basis of the known resources of Europe and America. It is assumed that the resources of these countries are likely to be in some proportion to the areas, which, as the geological principles involved are the same in both cases, is not too unreasonable an assumption for the purpose in view. The ton-mile factor for the known continents works out at 1,646 tons per square mile. Applying this to the areas of the unknown continents we get a figure of 52,200 million tons for the reserves, which, added to the figure already obtained for Europe and America, gives a grand total of 84,000 million tons for the world's resources of commercial ore, in the sense of the present-day usage of the term.

On the whole adequate iron-ore supplies for the chief smelting centres of the world seem reasonably secure for a remote future. One fact, important for the makers of hæmatite steel, clearly emerges, and that is the relative scarcity of low-phosphorus ore. Excepting the great reserve of the very highest quality ore in Brazil the known

reserves of low-phosphorus ore in the rest of the world only amount to some 1,740 million tons, the bulk of which is in the United States. The European resources of this class of ore are small and rapidly diminishing, and the claims on them are increasing. Spain is engaged in the development of a new iron and steel industry, and France will require a larger proportion of the North African ore. The British ironmaster, if he is to continue making hæmatite steel, will sooner or later be driven to seek his ore supplies outside Europe, and that indicates Brazil as the future main source of this class of ore.

REVIEWS.

GEOCHRONOLOGISCHE STUDIEN ÜBER DIE SPÄTGLAZIALE ZEIT IN SÜDFINNLAND. By MATTI SAURAMO. Bulletin de la Commission Géologique de Finlande, No. 50. Helsingfors, 1918.

THE extension into Finland of Professor De Geer's method of obtaining the time-values of the stages of glacial retreat is an event well worthy of note. Dr. Sauramo's memoir deals with a considerable area of Southern Finland, both north and south of the great Finnish end-moraine known as the Salpausselkä. This region was largely submerged beneath the Late-Glacial or Yoldia Sea, the sedimentation in which was controlled by the flood waters from the retreating ice-sheet. The summer floods brought coarse sandy sediments; the winter cold reduced the glacial outflow, and the finer silts and clays were deposited at this season. There has resulted an annual lamination, which, strange to say, is so remarkably constant over wide areas that correlation from place to place is possible. The method of correlation introduced by De Geer, and applied by him with such spectacular success in Sweden, consists in drawing graphs along the axes of which are marked equal intervals representing the years, and erecting ordinates proportional to the thickness of the corresponding laminæ. The graphs of the different sections can then be compared by sliding them over one another until a coincidence is obtained sufficiently remarkable to establish identity.

The distances over which Professor De Geer effected these correlations were considerable, but it is more than surprising to learn that they can be carried out with a fair amount of success by direct comparison between sections some 200 miles apart on opposite sides of the Baltic. Seven sections, which the author of the paper under review ultimately fitted into the Finnish chronology, were sent to De Geer without localities or other clue to their identification. In the case of five of these he attempted a correlation with the Swedish record, but failed in two instances, with regard to one of which he had expressed doubt. The remaining three he placed in the correct relation to one another, in which they ultimately worked out in the Finnish record, and dated two of them with respect to the third with an error of less than five years in a thousand.

A study of the laminated clays corresponding to the stages of halt in the retreat, the most important of which are those marked by the inner and outer wreaths of the Salpausselkä, has rendered possible very accurate estimates of the duration of these stages, and brought out clearly the fact that they are periods of minimum summer ablation. The coarse summer zone, instead of forming the greater proportion of each year's sedimentation, is reduced to a negligible thickness or disappears altogether. The halt is thus

obviously due to a drop in the summer temperature. A drop in the mean annual temperature cannot be deduced, but is probable. The important point is, however, that the halt is due to a temperature change, and not to a change in the precipitation or nourishment of the ice-sheet. This conclusion, which was also reached by De Geer in Sweden, is in itself very interesting, as it is obvious that a halt might be conceived to result from increased precipitation on the snowfields, producing an active thrust forward of the glacier front, and so balancing the marginal wastage. This, however, is only incidental to the main point, which it is the object of this review to emphasize, and which appears to be quite novel.

When the successive positions of the ice-margin are laid down on a map, or, more strikingly still, when the rate of retreat is plotted as a curve against the years, it becomes apparent that periods of halt in retreat were followed in nearly all cases by unusually rapid withdrawal, which gradually in the course of ten or fifteen years reverted to the normal rate characteristic of that stage of the retreat in general. This does not appear to have been due to excessive ablation, for the summer sediments in the laminated clays corresponding to these periods of rapid retreat have no exceptional thickness, and Dr. Sauramo draws the conclusion that during the cold period of the halt the ice-sheet had become thinner and so yielded more rapidly at its margin, once melting set in again.

Here, then, is additional light on the climatic condition of the halt-stages. Wastage was in progress during these periods, but was not, to any great extent, effected by the process of ablation. The ice surface was being lowered by some agent independent of ablation. There seems to be only one physical process that could account for such a remarkable phenomenon, namely, direct evaporation from the ice. This is, of course, well known to be physically possible, but it has certainly never been appreciated by geologists as an effective agency in glacial control. If it be now admitted as a result of this work of Dr. Sauramo's that such is the case, and that under sufficiently low conditions of temperature the wasting effects of direct evaporation may become comparable with those of ablation, or possibly exceed them, such a conclusion must modify all our notions of the growth and ultimate decay of ice-sheets.

W. B. Wright.

Contributions to the Knowledge of the Reptiles of the Karroo Formation. By Dr. E. C. N. van Hoepen. Annals of the Transvaal Museum, vol. vii, pt. ii, 1920.

THE author describes a new genus of Dinosaur from the Stormberg beds, and designates it *Aristosaurus erectus*. The animal was of small size and highly specialized. It shows adaptation to a bipedal mode of locomotion. The humerus is relatively much shorter than in other Anchisauridæ, the family to which it belongs.

In a second paper the author gives an account of two new genera of Theropoda; the bones of various known species are also described. Both papers are illustrated by excellent photographic reproductions.

F. H. A. M.

NOTES ON THE GEOLOGY AND IRON ORES OF THE CUYUNA DISTRICT, MINNESOTA. By E. C. HARDER and A. W. JOHNSTON. Bull. 660–A, U.S. Geol. Survey. pp. 26, with one map. 1917.

IN its geological features the recently developed Cuyuna range strongly resembles other iron-producing areas of the Lake Superior region. As elsewhere, the ores belong to the pre-Cambrian and present the same types of ore and country rock. The region is almost entirely covered by a thick mantle of drift, and it is of great interest to find that the discovery of iron-ore was entirely due to the existence of abnormal magnetic conditions. The occurrence of these abnormalities has long been known, but iron-bearing rocks were first proved by boring in 1904, and production began in 1911.

The rocks of the region, so far as known, are generally considered to be equivalent to the Virginia slate of the Mesabi district, but much more detailed work is required before this correlation can be regarded as proved. They have been invaded, after the principal metamorphism, by igneous intrusions, supposed to be of Keweenawan age; here and there are outliers of Keweenawan lavas and of Cretaceous sediments.

The iron-bearing rocks are folded into a complex series of N.E.–S.W. synclines and anticlines, forming a south-west extension of the Lake Superior synclinorium; the predominant dips in both limbs of the folds are to the south-east. The ore-bodies are exactly similar in general character to those of other ranges, showing a wide variation of type. The best quality yet known, a soft blue hæmatite from the Croft Mine, runs up to 67 or 68 per cent metallic iron, with very low phosphorus; the main part of the output consists of ore with 58 to 60 per cent iron and running up to 0·4 or 0·5 per cent phosphorus.

R. H. R.

SOUTH AUSTRALIA DEPARTMENT OF MINES. Mining Review, No. 31. Adelaide, 1920.

THIS half-yearly volume contains statistics of mineral production in the State for the whole of 1919. The general results appear satisfactory, considering the present industrial conditions. The serious diminution in the output of copper has been to a certain extent counterbalanced by the increase in iron-ore, which, for the first time, takes the leading place in value.

Among the special reports those of most general interest are the Second Summary Report on the utilization of Leigh Creek coal and an account of the manganese deposits worked by the Australian Manganese Company at Pernatty. A short account is also given

of the Australian Slate Quarry, Willunga, which works a belt of slate of late pre-Cambrian or Lower Cambrian age, apparently of very good quality.

Polarized Light in the Study of Ores and Metals. By F. E. Wright. Proc. Amer. Phil. Soc., vol. lviii, 1919, pp. 410–47.

Examination of Ores and Metals in Polarized Light. By F. E. Wright. Mining and Metallurgy, No. 158, 1920.

THE first of these papers gives an elaborate mathematical analysis of the theory of reflection of polarized light from polished surfaces of opaque substances, together with a description of various forms of optical apparatus adapted to determine the isotropic or anisotropic character of such substances; in certain cases the strength of the double refraction can be determined approximately. Methods involving the use of a bi-quartz-wedge-plate are the simplest, and have given the best results. In general, refractive indices cannot be ascertained on small polished random sections. The second paper contains a similar account of the practical application of these methods, with descriptions of the apparatus used by the author in his investigations.

REPORTS AND PROCEEDINGS.

Edinburgh Geological Society.

March 17, 1920.—Mr. E. B. Bailey, M.C., B.A., F.R.S.E., F.G.S., President, in the chair.

1. "Notes on the Glacial and Post-Glacial Geology of the Dee Valley, from Balmoral to Aboyne." By Dr. Alex. Bremner, Aberdeen.

A glaciation map of the district was exhibited. In all 220 hitherto unrecorded striæ had been noted. There was no marked difference in direction between striæ due to the Ice Sheet and those due to the Valley Glacier. Lateral moraines and the terraces usually called "fluvio-glacial" were discussed. Of the latter there were many fine and hitherto unmapped examples. The effects of marginal drainage were very well exemplified in the district, and it was suggested that the truncation of spurs might be due in great measure to the cutting of marginal channels during the advance of glacier or ice sheet. Maps showing the river terraces were exhibited, and discrepancies between these and the Geological Survey maps pointed out. It was shown that there was no evidence for the former existence of a lake below Ballater.

2. "River Terraces." By Dr. Alex. Bremner, Aberdeen.

The contributions of Hugh Miller, jun., and Professor W. M. Davis to the theory of river terracing were reviewed. The former, who gave an adequate explanation of amphitheatre terraces (i.e. terraces having a front, on the whole, convex towards the river),

and junction terraces, was not clear as to the mode of formation of what he himself called "the lateral terrace proper". Under that head he seemed to include (1) terraces with straight or slightly curved, nearly parallel front and back margins, and (2) terraces with strongly curved back margins concave towards the river. Professor Davis, elaborating an idea little more than suggested by Miller, propounded in his paper on "The River Terraces of New England" a satisfactory theory, not so much of terrace-formation as of *terrace-preservation*. "The lateral terraces proper" of Miller, particularly (2) above—the most difficult of all to account for—still required explanation. Such terraces had evidently been swept out in the first instance by pronounced and fairly persistent bends, to which the characteristic curves of their back margins was due. In the case of the Dee, the river was not withdrawn by short-circuiting across the necks of the spurs within the bends; for the slope of such terraces was, on the whole, towards, not away from the present course of the river. The conditions determining the formation of river islands and their incorporation in the flood-plain were discussed in detail. It was pointed out that every terrace of any extent along the Dee was traversed by a larger or smaller number of anastomosing hollows, plainly former channels of the river or of branches of it; and that terraces of all types had been built up by the accretion of island to island through the desertion and subsequent partial obliteration (by flood-loam, etc.) of secondary channels. The process was shown to have illustrations elsewhere; and the principle involved was no doubt of wide application in the case of rivers of fairly steep gradient whose flood-plain, like that of the Dee, was practically coextensive with their meander belt.

3. "A Rhomb Porphyry Boulder from the Glacial Deposits at Bay of Nigg, Aberdeen." By Dr. Alex. Bremner, Aberdeen.

The Rhomb Porphyry—a boulder weighing 32 lb.—was found 15 feet above H.W.M.O.S.T. in a boulder-bed, far too coarse to be called a gravel, underlying the Lower Grey Boulder Clay of the Aberdeen district (see Trans. Edin. Geol. Soc., vol. x, pt. iii, p. 345). The probable ways in which it might have reached the place where it was found were discussed, and the resemblance between the glacial sequence at Bay of Nigg and that on the Yorkshire coast was pointed out. This was the first record of the occurrence of a Scandinavian boulder, *in situ* in glacial deposits, on the mainland of Scotland.

Institution of Mining and Metallurgy.

October 21, 1920.

"The Origin of Primary Ore Deposits." By J. Morrow Campbell, D.Sc., F.G.S.

The author commences at the period when the outer silicate shell of the earth was molten. The primeval magma is regarded as having

been practically homogeneous and containing about 60 per cent of combined silica. All water was then in the atmosphere. As temperature fell water and oxygen were absorbed, crust-formation, foundering, and resorption went on for a long period, producing a flat temperature-gradient in the liquid. When the crust became permanent, granite developed, and below it basaltic magma long remained liquid. At this stage the isostatic balance was adjusted. Ore-minerals in large quantity were given off at the surface of the granite, were denuded, and dispersed in sediments and solution. This, with subsequent absorption by basaltic magma, is assumed to have been instrumental in causing the present erratic distribution of primary ores.

Magmatic differentiation is regarded as having been caused by the agency of silicic acid—silicon combined with hydroxyl—which extracts potash alumino-silicate, producing a solution immiscible with and lighter than a melt of basic felspars and femic minerals.

Evidence regarding the existence of silicic acid in magmatic liquids and elsewhere in nature is recited.

The ultimate result of the action of water on rock magmas is that silicates are completely removed and a residue of ore-minerals—magnetite, etc.—left.

Vein fissuring is held to have been brought about in and above batholiths by the expansive force due to the increase in solid specific volume of various elements. The effect of this force appears in waves as successive series of fissures. These developed very rapidly, were instantly filled with magmatic mother-liquor, and quickly sealed by the deposit of solids therefrom. It is argued that primary ore-minerals passing up from magmas to veins do so in silicic acid solution; that their deposition is determined both by loss of heat and reduction of pressure; and that there are definite but narrow limits of temperature between which each ore-mineral develops.

Reasons are given why the pneumatolytic origin of tin and tungsten ores should be rejected.

Cornish Institute of Engineers.

September 16, 1920.

"On the Characters of some Cornish Veinstones." By the President, Mr. E. H. Davison.

The paper gives the results of the examination of a number of Cornish lodes. Those not at present being worked were represented by isolated specimens from known points in the lode, while the lodes now working were systematically sampled down the dip.

The methods employed included microscopic and microchemical examination as well as in some cases mechanical analysis. It was considered that three types could be recognized which were related to the surface of the nearest granite mass.

1. Quartz-wolfram lodes. Little cassiterite, sulphides, or tourmaline, characteristically no chlorite. Upper level of tin and tungsten zone. Occurring in the slate or just in the granite, at or near the crest of the mass.

2. Quartz-chlorite-wolfram-cassiterite-mispickel lodes. Chlorite predominant over tourmaline. Cassiterite usually more than wolfram. Sulphides common. Middle of tin-tungsten zone.

3. Quartz-tourmaline-cassiterite lodes. Tourmaline predominant. Wolfram absent. Sulphides absent or subordinate. Lower part of tin-tungsten zone. Occurring in depth in the granite.

It was also noted that if wolfram was present in the lode, copper was absent or subordinate. The detailed microscopic characters of the veinstones were given in tabular form at the end of the paper.

CORRESPONDENCE.

PHYSIOGRAPHIC RELATIONS OF LATERITE.

Sir,—In reply to Professor W. M. Davis's inquiry in the September number of this Magazine, I should in the first place explain that my paper on Lateritization in Sierra Leone was concerned essentially with the chemical and mineralogical changes undergone by the different rocks of the country in the course of their transformation into laterite, and only to a minor extent with the relation of the laterite to surface forms and physiographic old age. Nevertheless, I am indebted to Professor Davis for directing my attention to several additional points of interest.

In Sierra Leone, as elsewhere in the tropics, laterite is in general best developed on surfaces of gentle slope or low relief, as the following examples from different parts of the country will show:

1. *The Coastal Plain.*—This plain, which along the inner margin rises to a height of about 400 feet above sea-level, consists of sediments, probably of Pleistocene age, which are still in process of lateritization. Locally on these sediments there occur large bare sheets of laterite, free from vegetation and soil, similar to those described by Mr. Morrow Campbell,[1] and explained by him as due to rapid growth of highly ferruginous laterite; this laterite diminishes the fertility of the soil, which, losing the protection of the dying vegetation, becomes gradually washed away by the torrential rains.

2. *The Crystalline Rocks of the Lowlands.*—These rocks under the following conditions are in general deeply kaolinized and lateritized—

(*a*) Where rising as low hills above the sediments of the coastal plain:

(*b*) On those undulating areas in which the plain merges along its

[1] "Laterite, its Origin, Structure, and Minerals": *Mining Mag.*, vol. xvii, 1917, p. 178.

inner margins into the uplands. Where, on the other hand, the change from coastal plain to upland or plateau country is abrupt, and the relief of the crystalline rocks is considerable, altered rocks are rarely seen and laterite is practically absent.

3. *Ancient Sedimentary Rocks of the north-west corner of the Protectorate.*—These sediments, which do not depart greatly from the horizontal, are capped by a great thickness of dolerite. The sediments and the dolerite, together with the underlying crystalline rocks, form a great scarp over 2,000 feet in height. Laterite is well developed on the dolerite, but it is now undergoing extensive erosion.

4. *The Norite of the Colony.*—Laterite is best developed on certain ancient platforms carved into the mountain mass.

5. *The Great Plateau forming the north-eastern part of the Protectorate.*—Over a large portion of this plateau, away from the margins, conditions are very different from those considered above, because an extensive area of the crystalline rocks, which make up the plateau, is overlain by a sand formation,[1] which so far has not been observed in any other part of the country. This sand formation locally attains a thickness of more than 300 feet. It is undergoing extensive erosion, which has resulted in the central areas of the sand-sheet in the carving of deep valleys, at the bottoms of which the crystalline rocks are again exposed; towards the margins of the sheet the sands appear as numerous flat-topped and conical hills, and finally, along the limits of the sheet, the sands form only a few caps on the crystalline plateau. This plateau is generally well-defined, although it is for the most part trenched by steep-sided valleys; locally erosion has proceeded much further. The upper surface of the main sheet of the sands consists of a series of plateaux, which do not differ greatly in height. Laterite is developed on the sands and on the crystalline rocks as follows:—

(*a*) The Sands.—The laterite forms a continuous crust, rarely exceeding 2 feet in thickness, on the surfaces of the plateaux and on the flat-topped hills. The laterite of the higher plateaux must be regarded as older than that of the lower. On the sides of the hills laterite does not occur except as fallen blocks, and on the low ground between the hills it is developed only as occasional thin patches of gravel.

(*b*) The Crystalline Rocks.—Laterite has very rarely been observed on these rocks within the limits of the sand formation. The sands, often containing near their base fragments of the country rocks, frequently rest upon a perfectly fresh surface; elsewhere they rest upon a surface which is variably, but not deeply, kaolinized. Sometimes, far beyond the present limits of the sand-sheet, there occur extensive flat or gently convex areas of the crystalline rocks, chiefly

[1] I have recently given a brief description of these sands and the ferruginous laterite capping them; see "Primitive Iron-ore Smelting Methods in West Africa": *Mining Mag.*, October, 1920.

granites; these areas, which are quite bare except where covered by occasional clumps of grass, are remarkable in being quite fresh, showing no signs of weathering or any other kind of alteration. The absence of laterite on such surfaces has been explained by Mr. Morrow Campbell, who has paid much attention to the conditions under which rocks become kaolinized and lateritized in the tropics. This writer considers that crystalline rocks must be altered before they can be lateritized, and also that the alteration necessary, generally kaolinization, can be produced only when the rocks have been for a long time continuously in contact with vadose water, i.e. in the zone of permanent saturation.[1] Accordingly, the fresh surface rocks referred to above, not having been subjected to such conditions, remain unlateritized.

F. Dixey.

University College, Cardiff.
October 4, 1920.

AN UNDESCRIBED SPECIES OF *TROCHILIOPORA*.

Sir,—I desire to draw attention to a band of Chalk in Sussex, about 10 feet thick, near the base of the zone of *Micraster coranguinum*, in which an undescribed Polyzoon belonging to the genus *Trochiliopora* is very common. As this fossil appears to be confined to the said band of Chalk, and also owing to its abundance, it has proved to be a very useful local zonal guide fossil. The exact position in which it occurs in the *Micraster coranguinum* zone is as follows:—

Lower fourth of zone of *Micraster coranguinum*.	Strong *M. coranguinum* tabular flint band.	
	Chalk, about 35 feet.	
	Chalk with *Trochiliopora* sp., 10 feet.	
	Chalk, about 17 feet.	
Chalk of zone of *Micraster cortestudinarium*.		

I propose to call the 10 feet of chalk referred to "the *Trochiliopora* bed".

The genus *Trochiliopora* has been described by Professor J. W. Gregory in the Geological Magazine, 1909, p. 65, and also in the British Museum Catalogue of Cretaceous Bryozoa, vol. ii, p. 265. The species above referred to resembles *T. humei*, Gregory, but its body tapers to a much finer stem than the stout blunt stem of the latter species.

The *Trochiliopora* bed is rich is Polyzoa, it having yielded some rare and interesting forms.

Christopher T. A. Gaster.

Lewes, Sussex.
October 4, 1920.

GEOLOGY OF THE NINGI HILLS.

Sir,—Major Williams' paper on the geology of the Ningi Hills of Nigeria in the October number is very welcome. It indicates not

[1] Morrow Campbell, op. cit., p. 123.

only an increasing interest by the mining community in the geology of the Nigerian tinfields, but also, I hope, an increasing disposition to publish geological observations thereon. Major Williams, however, will agree that in view of local controversies it is important that facts and conclusions should be correctly stated and deduced, and I may therefore perhaps be allowed to make the following remarks upon his paper.

Major Williams makes no mention of the fact that I mapped and described in 1911, in my "Geology and Geography of Northern Nigeria", the younger riebeckite-granites of Ningi, Kila, and Fagam, with which a portion of his paper is concerned. Of the country between Buji and Ningi, I have little personal knowledge, but from what I have gathered in conversation with capable observers who have repeatedly traversed it, and from what I know of the adjoining parts of the tinfields, I feel sure that there are there not extensive outcrops of an older riebeckitic Sabon Garri granite, but a number of outcrops of younger riebeckite-granite projecting through older micaceous gneisses of various types. In spite of the assertion to the contrary in the appendix on p. 446, the petrographical descriptions do not confirm the hypothesis of an older series of intrusions "specially characterized by perthite, riebeckite, and ægirine". Of the sections quoted in support Nos. 106, 108, 110, C.C. 3, and C.C. 4 contain no perthite, riebeckite, or ægirine; No. 113 is valueless as evidence; No. 115 is said on one page to be "slightly crushed" and on another to show "no sign of crushing" and to belong "to the younger series", while Nos. 100 and 105 are simply sections of normal younger granite.

It would also be interesting to know how Major Williams arrives at his belief that the younger granites of Nigeria are of Mesozoic age. It may be on account of the relative freshness of their outcrops, as in the case of the Tertiary (?) gabbro dyke of Keffi Filani. In any case the distinction of Archæan and Mesozoic soda-granites in Nigeria cannot be considered established, while the generalization that "tin is only found in granites that contain riebeckite" is true only in the sense that tinstone is associated with the younger granites, which may or may not carry riebeckite.

J. D. Falconer.

London.
October 13, 1920.

OBITUARY.

Sven Leonhard Törnquist, Ph.D., F.M.G.S.

Born March 6, 1840. Died September 6, 1920.

The study of Graptolites has in the last few years suffered the loss of some of its veteran workers, and to the names of Hopkinson and Lapworth must now be added that of the Swedish geologist, S. L. Törnquist. Born at Uddevalla in 1840, he proceeded in due